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STUDIES ON PENAEIDS OF JAPANESE AND ITS ADJACENT WATERS*

BY

ITSUO KUBO

(With 160 Text-figures)

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I. Introduction

In regard to the Penaeids of Japanese and adjacent waters, many systematic studies were made by various investigators, such as H. MILNE-EDWARDS (1837), DE HAAN (1850), STIMPSON (1860), MIERS (1878), ORTMANN (1890), WOOD-MASON and ALCOCK (1891), KISHINOUYE (1900), RATHBUN (1902), DE MAN (1907 and 1911), BALSS (1914), PARISI (1919), MAKI and TUTIYA (1923), YOKOYA (1933), OSADA, TANIZAKI and NAKAZAWA (1936), YOSHIDA (1941), and others. Yet much has been left to be desired in this connection up to the present day. Moreover, the genealogical relationship among the subfamilies, genera, and species is not known satisfactorily. To give more precise foundament for the taxonomy and to interpret more exactly the inter-relationship, the present scrutiny was undertaken with special reference to the annexed items, viz., general feature of carapace, telson, ophthalmopod, antennule, mouth-parts, orthogenetic organs, appendix masculina, and stomodaeal ossifications; arrangement of basial, ischial, and meropoditic spines, as well as exopodite of thoracic appendages, and branchiae; and metamorphosis of petasma, thelycum, and appendix masculina.

Some species of Penaeids so closely resemble each other in general facies that they are not precisely distinguished from one another unless the relative length of body-parts in accordance with age or meristic characters are taken into consideration. Hence the biometric treatment for the discrimination of species and subspecies was resorted to, with the result that the accumulated data enabled the writer to make emendation of, or addition to, definitions of species, genera, subfamilies, and even a family, and also creation of several systematic categories.

The material on hand consists of a large number of specimens referable to 4 subfamilies, 16 genera, 67 species, and 1 subspecies. Considerably emended are two subfamilies, and most genera. Proposed new to science are two genera and 21 species are found new to the Japanese fauna. Unfortunately, however, the following already recorded species are not represented in my material:—*Benthesicymus altus* BATE, *Gennadas parvus* BATE, *Gennadas almani* KEMP, *Hepomadus glacialis* BATE, *Aristaeopsis armatus* (BATE), *Solenocera distincta* DE HAAN, *Trachypenaeus pescadoreensis* SCHMITT, *Metapenaeopsis mogiensis* (RATHBUN), *Metapenaeopsis kyushuensis* (YOKOYA), and *Penaeus semisulcatus* DE HAAN. Of the abovementioned nine species, some appear doubtful, and some are perhaps misnomers.

The list given below embraces all the examined species with reference to the geographical distribution. Asterisks mark those which are new to Japan.

Subfamily Aristaeinae

Genus *Aristaeomorpha*, WOOD-MASON

* *A. foliacea* (RISSO)	Japan (Pacific coast), Australia (South-East coast), Mediterranean, East Atlantic.

Genus *Aristaeus* DUVERNOY

* *A. virilis* BATE	Indopacific.

Subfamily, Solenocerinae

Genus *Solenocera*, H. LUCAS

S. alticarinata sp. nov.	Formosa
S. prominentis sp. nov.	Japan (Kumanonada, and Tatugahama, Wakayama Pref.).
S. depressa sp. nov.	Japan (Kumanonada, and Nagasaki).
S. faxoni DE MAN	Japan (Kumanonada), East Indian Archipelago.
S. brevipes sp. nov.	Japan (Kumanonada, and Tateyama-wan, Tiba Pref.).
S. pectinulata sp. nov.	Japan (Kumanonada).
S. subnuda sp. nov.	Off South coast of Borneo.

Genus *Hymenopenaeus*, SMITH

* *H. lucasii* (BATE)	Japan (Kumanonada), Indo-Pacific.
* *H. aequalis* (BATE)	Japan (Kumanonada), Indo-Pacific.

Genus *Parahaliporus* gen. nov.

P. sibogae (DE MAN)	Japan (Kumanonada and Suruga-wan), East Indian Archipelago.

Subfamily Penaeinae

Genus *Miyadiella* gen. nov.

M. pedunculata sp. nov.	Japan (Osaka-wan and Nanao-wan).

Genus *Penaeus* FABRICIUS, emend.

P. japonicus BATE	Indo-Pacific.
P. latisulcatus KISHINOUYE	Indo-Pacific.
P. longistylus KUBO	Off South-East coast of Hainan Island.
P. brevirostris KINGSLEY	West coast of America.
P. teraoi sp. nov.	Japan (Miya, Aiti Pref.).

P. monodon FABRICIUS	Indo-Pacific.
P. bubulus sp. nov.	Indo-Pacific.
P. orientalis KISHINOUYE	Yellow Sea, and East China Sea.
P. penicillatus ALCOCK	Formosa Western Indo-Pacific.
P. merguiensis DE MAN	Western Indo-Pacific.
P. indicus H. MILNE-EDWADS	Bangkok, Western-Pacific.
P. vannamei BOONE	Pacific coast of Central America.
P. esculentus HASWELL	South coast of Borneo, East coast of Australia.
P. stylirostris STIMPSON	Pacific coast of Central America.

Genus *Penaeopsis* BATE, emend.

* *P. rectactus* (BATE)	Japan (Kumanonada, and Heta, Shizuoka Pref.),

Genus *Metapenaeus*, WOOD-MASON and ALCOCK, emend.

M. monoceros (FABRICIUS)	Indo-Pacific.
M. intermedius KISHINOUYE	Japan (Wakayama, Mie, and Koti Prefs.).
M. affinis (H. MILNE-EDWARDS)	Indo-Pacific.
M. joyneri (MIERS)	Japan.
M. tenuipes sp. nov.	South coast of Borneo.
M. brevicornis (H. MILNE-EDWADS)	Indo-Pacific.
M. spinulatus sp. nov.	Bangkok.
M. lysianassa (DE MAN)	Singapore, East coast of Bengal Bay, and coasts of India.

Genus *Trachypenaeopsis*, BURKENROAD

* *T. richtersii* (MIERS)	Japan (Miye, Aiti, Pref.), Indo-Pacific.

Genus *Atypopenaeus*, ALCOCK

A. compressipes (HENDERSON)	Japan (Inland Sea), Indo-Pacific.

Genus *Parapenaeopsis*, WOOD-MASON, emend.

P. tenellus (BATE)	Japan.
P. cornutus (KISHINOUYE)	Japan (Ariake-kai, Kyûsyû), Indo-Pacific.
P. maxillipedo ALCOCK	South coast of Borneo, and coasts of India.
P. hungerfordi ALCOCK	Amoy to Singapore.
P. gracillima NOBILI	Malay Sea.
P. hardwickii (MIERS)	Chusan Islands (near Shanghai), South coast of Borneo, Singapore, coasts of India.
P. cultrirostris ALCOCK	Amoy, South coast of Borneo, coasts of India.
P. sculptiris (HELLER)	Amoy, Borneo, and coasts of India.

Genus *Trachypenaeus*, ALCOCK, emend.

T. curvirostris (STIMPSON)	Japan, and South coast of Borneo.
T. asper ALCOCK	South coast of Borneo and coasts of India.

Genus *Parapenaeus* SMITH, emend.

P. fissurus (BATE)	Indo-Pacific.
P. sextuberculatus sp. nov.	Japan (Heta, and Maisaka, Shizuoka Pref.).
P. lanceolatus sp. nov.	Japan (Heta, Shizuoka Pref., Kumanonada, Off Owase, Mie Pref.).
* *P. investigatoris* ALCOCK and ANDERSON	Japan (Maisaka, Shizuoka Pref.), Kei Islands,

Genus *Metapenaeopsis* BOUVIER, emend.

M. barbatus (DE HAAN)	Japan.
M. acclivis (RATHBUN)	Japan.

M. durus sp. nov.	Japan (Tokyo fish market, and Miya, **Aiti Pref.**).
M. incomptus sp. nov.	East China Sea.
M, dalei (RATHBUN)	Japan.
M. lamellatus (DE HAAN)	Japan.
M. coniger (WOOD-MASON)	Japan (Maisaka, Shizuoka Pref., and off Kôti), East coast of India, Andaman Sea.
M. latus sp. nov.	Japan (off Nagasima, Mie Pref.).

Subfamily Eusicyoninae

Genus *Eusicyonia* STEBBING, emend.

E. lancifer japonica BALSS	Japan.
E. cristata DE HAAN	Japan.
E. vitulans sp. nov.	Japan (Kumanonada, off Owase, Mie Pref.).
E. curvirostris BALSS	Japan.
E. nebulosa sp. nov.	Japan (Heta, Shizuoka Pref.).
E. truncata sp. nov.	Japan (Kumanonada, off Kôti, Shikoku).
E. inflexa sp. nov.	Japrn (Kumanonada).

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III. Material and Methods

The material on which the present investigation is based was secured from various localities of Japan as well as from the following Southern districts, viz., Chusan Islands, East China Sea; off South-East coast of Hainan Island; Bangkok, Tai; Singapore; South coast of Borneo, and Macassal, Celebes. Most of the southern specimens were collected by the training ship, *Hakuyô-Maru*, of the Imperial Fisheries Institute, Tokyo. Besides these, a number of Pacific American specimens referable to three species: *Penaeus brevirostris*, *P. stylirostris*, and *P. vannamei*, were examined.

The measurement of various parts of body was made as indicated below.

a. The body-length is represented by the distance between the post-orbital margin and tip of telson.

b. The carapacial-length is determined by a measurement from the post-orbital border to the posterior edge.

c. The rostral length is a distance measured from the lower base to the apex.

d. The rostral width is obtained by a vertical distance between ventral and dorsal borders with teeth inclusive.

e. The length of abdominal segment is measured from anterior rim to posterior one along dorso-median line.

f. The length of telson means the distance between the proximal edge and the tip.

g. The width of telson is measured in the broadest region.

h. The length of antennal scale is represented by the distance from the base to the apex of the lamella.

i. The length of third maxilliped and all pereiopods is measured from anterior base to distal end of the dactylus, and that of each component joint of these appendages is indicated by the distance measured dorsally or anteriorly between proximal and distal ends.

The minute observation of the following organs was made on the material stained black, viz., dorso-lateral spinules of telson, petasma, thelycum, appendix masculina, and pattern of setose areas of the carapace and pleon.

The stomodaeal apparatus was dissected out from adult specimens preserved in alcohol, and mounted for observation after cleaning off the muscles laid down on outer surface of the chitinous lining, on which the stomodaeal ossifications are developed.

IV. General Part

1. EXTERNAL CHARACTER

A. ROSTRUM

All the Penaeids dealt with herein are furnished with well developed rostrum. Typically the rostrum is styliform, fixed and rigid, provided with a low lateral ridge on either side arising from each orbital margin, and armed with teeth. But it undergoes considerable variation in its inclination, length, relative length against carapace, and in number of the teeth.

The inclination varies from almost horizontal to about 35°, but mostly horizontal.

The proportion in length to carapace is subject to considerable interspecific and intraspecific variations, ranging from 0.18 to 1.3 throughout all the examined species. With regard to 22 species, viz., *Aristaeomorpha foliacea, Aristaeus virilis, Parapenaeopsis hardwickii, Metapenaeopsis barbatus, M. lamellatus, M. dalei, M. acclivis, Metapenaeus affinis, M. monoceros, M. joyneri, Penaeus monodon, P. bubulus, P. japonicus, P. latisulcatus, P. orientalis, Penaeopsis rectactus, Parahaliporus sibogae, Solenocera brevipes, Atypopenaeus compressipes, Trachypenaeus curvirostris, Eusicyonia cristata*, of which a large number of specimens were obtained, the proportion, when plotted in relation to carapace-length, shows three different types in trend, viz., Types, *A–C*. The proportion at first increase but afterwards decreases in accordance with growth of carapacial length in Type–*A*.; it simply decreases in Type–*B*; and almost constant in Type–*C*. Type–*A* is found in annexed four species: *Metapenaeopsis barbatus, M. dalei, Metapenaeus affinis*, and *Penaeopsis rectactus* (Fig. 1, *D, E, H*, and *L*). The length of carapace when the trend changes downward is about 15 mm in *M. barbatus*, 16 mm in *M. dalei*, 17 mm in *M. affinis*, 20 mm in male and 25 mm in female of *P. rectactus*. Type–*B* is found in the following 13 species: *Aristaeomorpha foliacea, Aristaeus virilis, Parapenaeopsis hardwickii, Penaeus monodon, P. bubulus. P. japonicus, P. orientalis, P. latisulcatus, Metapenaeus monoceros, M. joyneri, Metapenaeopsis lamellatus, Parahaliporus sibogae, Eusicyonia cristata* (Fig. 1, *A–C, G–I, K, O–R*, and *U*.); Type–*C* in the rest: *Metapenaeopsis acclivis, Atypopenaeus compressipes, Trachypenaeus curvirostris, Parapenaeopsis tenellus, Eusicyonia inflexa* (Fig. 1, *M, N, S*, and *V*). Sexual difference is not found to exist in all other forms except *Penaeopsis rectactus* and *Metapenaeus joyneri*, in which the proportion in question is larger in female than in male.

Of the shape of rostrum, the following three types: Type–*L–M* and –*S*, may be recognized. Type–*L*, of which *Aristaeus virilis, Aristaeomorpha foliacea* and *Parapenaeopsis hardwickii* are comprised, is of very slender appearance. The proportion in length to carapace is more than 0.9. Distal about half of rostrum is rather recurved upward. Type–*M* is found in all species of *Penaeus, Parapenaeus, Trachypenaeus, Metapenaeopsis*, and *Eusicyonia*, and most species of *Metapenaeus* and *Parapenaeopsis*. In this type, the rostrum is moderate in general configura-

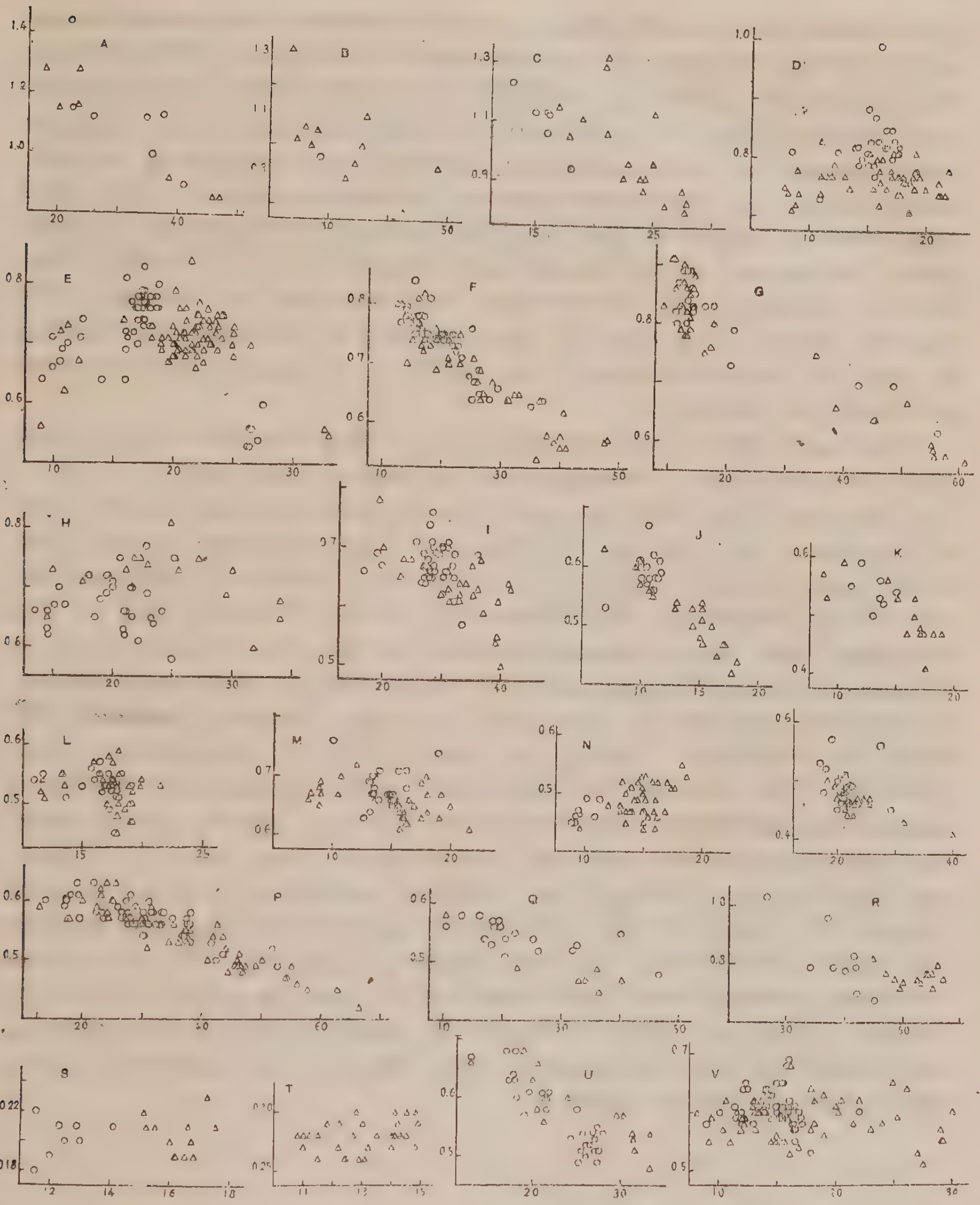

Fig. 1. Ratio of rostrum in length against carapace in reation to carapacial length (in mm). *A, Aristaeomorpha foliacea ; B, Aristaeus virilis ; C, Parapenaeopsis hardwickii ; D, Metapenaeopsis barbatus ; E, Metapenaeus affinis ; F, Penaeus monodon ; G, P. bubulus ; H, Penaeopsis rectactus ; I, Metapenaeus monoceros ; J, Eusicyonia cristata ; K, Metapenaeopsis lamellatus ; L, M. dalei ; M, M. acclivis ; N, Parapenaeopsis tenellus ; O, Parahaliporus sibogae ; P, Penaeus japonicus ; Q. P, latisulcatus ; R, P. orientalis ; S, Solenocera brevipes ; T, Atypspenaeus compressipes ; U, Metapenaeus joyneri ; V. Trachypenaeus curvirostris.*

tion, measuring 0.5 to 0.9 times as long as carapace, and mostly almost horizontal as in most species of *Penaeus*, *Parapenaeus*, *Metapenaeus*, *Parapenaeopsis*; sometimes uptilted as in some species of *Eusicyonia*, and distally reflexed as in some forms of *Metapenaeopsis* and *Penaeus*; rarely sigmoid as in *Parapenaeopsis sculptilis* and decurved as in *Parapenaeopsis tenellus* and young form of *Penaeopsis rectactus*. The third type, Type–*S*, which is seen in *Hymenopenaeus*, *Solenocera*, *Parahaliporus*, *Miyadiella*, *Atypopenaeus*, and *Trachypenaeopsis*, besides *Metapenaeus lysianassa*, is characterized by shortness of rostrum. The rostrum of this is less than 0.5 times as long as carapace, the shortest is found in *Solenocera brevipes*, in which it measures about 0.2 times the length of carapace.

In short, Type–*L* occurs least (4.6%), Type–*S* more (21.5%), and Type–*M* most (37.8%) throughout all the species dealt with.

The teeth that adorn the upper border of rostrum, are present without exception, but they are less than ten (even including all the postrostal ones) in number exclusive of only three cases, viz., *Penaeus latisulcatus*, *P. longistylus* and *Penaeopsis rectacus* (Tables 2 and 3). On the other hand, the armatures inserted on the lower border occur in *Penaeus* and such Penaeids as *Parahaliporus sibogae*, *Eusicyonia cristata*, *E. lancifer japonica*, *E. curvirostris*, and are, without exception, less than five in number. Presence of apical spines is particular to Eusicyoninae. The number of these teeth varies considerably within a species and specifically, but irrespective of sex. Among upper, apical and lower series of the teeth, the upper series is more variable in number than the rest. However, no definite correlation is found to exist between the number of the teeth and the length of rostrum, and between the number of the teeth and the length of carapace. The correlation coefficient computed for such items given above is smaller than ±0.5 without exception (Table 2). Finally the number of the teeth located on post-rostral carina is less variable than that of the teeth lying on the upper edge of rostrum (Table 3).

Table 1. Number of rostral spines. a, apical series; C. V., coefficient of variation; l, lower series; NO, number of available specimens; SD, standard deviation; u, upper series; *, obtained from South coast of Borneo; A, *Parahaliporus sibogae;* B, *Parapenaeopsis hardwickii;* C, *Penaeopsis rectactus;* D, *Solenocera brevipes*, E, *Aristaeomorpha foliace;* F, *Eusicyonia cristata;* G, *Penaeus bubulus;* H, *Penaeus monodon;* I, *Penaeus japonicus;* J, *Penaeus latisulcatus;* K, *Penaeus orientalis;* L, *Trachypenaeus curvirostris;* M, *Metapenaeus affinis;* N, *Metapenaeus joyneri;* O, *Metapenaeus monoceros;* P, *Atypopenaeus compressipes;* Q, *Metapenaeopsis lamellatus;* R, *Metapenaeopsis acclivis;* S, *Metapenaeopsis dalei;* T, *Metapenaeopsis barbatus.*

Species	No.	Items	Range	Mode	Mean	S. D.	C. V. (%)
A	41	u	6–9	7	7.39±0.07	0.72±0.05	9.85±0.73
A	41	l	1–3	2	2.04±0.03	0.37±0.02	18.52±1.42
B	26	u	7–9	8	7.69±0.07	0.54±0.05	7.10±0.70
C	23	u	8–13	11	10.91±0.13	0.97±0.09	8.92±0.88
D	20	u	5–6	6	5.70±0.06	0.45±0.04	8.04±0.85
E	15	u	8–12	9	9.60±0.17	1.01±0.12	10.62±1.32
F	36	a	2–4	3	3.22±1.05	0.47±0.03	14.83±1.20
G	56	u	7–8	7	7.16±0.03	0.36±0.02	5.12±0.32
G	56	l	2–3	3	2.91±0.02	0.28±0.01	9.80±0.62
H	76	u	6–8	7	7.78±0.08	1.11±0.06	14.27±0.79
H	76	l	2–4	3	3.26±0.06	0.84±0.04	26.00±1.51
I	105	u	8–10	9	9.28±0.03	0.49±0.02	5.29±0.24
I	105	l	1–2	1	1,02±0.01	0.16±0.00	16.20±0.77
J	26	u	9–12	10	10.00±0.09	0.70±0.06	7.07±0.66
K	22	l	7–9	8	8.27±0.08	0.61±0.06	7.45±0.75
K	22	u	3–5	4	4.00±0.07	0.52±0.05	13.05±1.40
L	105	u	6–8	6	6.53±0.03	0.57±0.02	8.72±0.40
M	128	u	6–8	7	7.07±0.03	0.51±0.02	7.32±0.30
N	44	u	6–9	8	7.59±0.06	0.61±0.04	8.10±0.58
O	50	u	6–9	8	7.84±0.05	0.61±0.04	7.80±0.52
P	29	u	6–8	7	7.31±0.21	1.68±0.14	23.01±2.14
Q	21	u	7–10	8	8.19±0.10	0.73±0.07	8.93±0.92
R	57	u	6–7	6	6.10±0.02	0.30±0.01	5.01±0.31
S	53	u	5–8	6	6.32±0.05	0.60±0.03	9.60±0.62
T	96	u	6–7	6	6.47±0.03	0.49±0.02	7.71±0.39
T*	33	u	6–7	7	6.66±0.05	0.47±0.03	7.07±0.58

Table 2. Correlation coefficient between the number of rostral spines and the carapace-length as well as rostral length. a, carapace-length; ap, apical series; b, rostral length; c, number of rostral spines; l, lower series; No., number of available specimens; r, correlation coefficient; u, upper series; *, obtained from South coast of Borneo.

Specific name	No.	Items	r_{ac}	r_{bc}
Parahaliporus sibogae	41	u	−0.31±0.09	−0.29±0.09
Parahaliporus sibogae	41	l	0.07±0.10	0.11±0.10
Parapenaeopsis hardwickii	26	u	−0.46±0.11	−0.12±0.25
Penaeopsis rectactus	23	u	0.42±0.11	0.40±0.11
Solenocera brevipes	20	u	−0.10±0.15	0.08±0.14
Aristaeomorpha foliacea	15	u	−0.27±0.16	−0.31±0.15
Eusicyonia cristata	36	ap	0.02±0.11	0.31±0.10
Penaeus bubulus	56	u	0.21±0.08	0.21±0.08
Penaeus bubulus	56	l	0.16±0.08	0.21±0.08
Penaeus monodon	76	u	0.24±0.07	0.48±0.05
Penaeus monodon	76	l	0.11±0,07	−0.23±0.07
Penaeus japonicus	105	u	0.05±0.06	0.20±0.06
Penaeus japonicus	105	l	0.04±0.06	0.04±0.06
Penaeus latisulcatus	26	u	0.25±0.12	−0.30±0.12
Penaeus orientalis	22	u	0.17±0.13	0.00±0.95
Penaeus orientalis	22	l	0.15±0,14	0.48±0.11
Trachypenaeus curvirostris	105	u	−0.41±0.05	−0.17±0.06
Metapenaeus affinis	128	u	−0.11±0.05	0.02±0.05
Metapenaeus joyneri	44	u	0.41±0.08	0.19±0.09
Metapenaeus monoceros	50	u	0.00±0.95	0.00±0.95
Atypopenaeus compressipes	29	u	−0.03±0.12	−0.06±0.12
Metapenaeopsis lamellatus	21	u	−0.03±0.14	0.17±0.14
Metapenaeopsis acclivis	57	u	−0.16±0.08	0.00±0.96
Metapenaeopsis dalei	53	u	0.38±0.07	0.06±0.09
Metapenaepsis barbatus	96	u	0.16±0.06	0,16±0.06
* *Metapenaeopsis barbatus*	33	u	0.15±0.11	0.20±0.11

Table 3. The types of the rostrum and number of the rostral spines. No., number of available specimens. The numerals given within brackets indicate the number of spines found on postrostral carina.

Specific name	No.	Type	Range		Mode	
			upper	lower	upper	lower
Aristaeomorpha foliacea	15	L	(2)+7-10		(2)+7	
Aristaeus virilis	13	L	(1)+2		(1)+2	
Miyadiella pedunculata	2	S	(3)+4-6	1		
Penaeus japonicus	105	M	(4-5)+4-6	1-2	(4)+5	1
P. bubulus	56	M	(3)+4-5	2-3	(3)+4	3
P. teraoi	12	M	(4-5)+5-6	1-2	(4)+6	2
P. longistylus	2	M	(5)+7	1		
P. penicillatus	9	M	(3)+4-5	4-6	(3)+4	5
P. merguiensis	8	M	(3)+4-5	4-5	(3)+4	4
P. indicus	2	M	(3)+4-6	4-5		
P. esculentus	2	M	(3)+3	2-3		
P. monodon	76	M	(3-4)+3-5	2-4	(3)+4	3
P. latisulcatus	26	M	(4-5)+5-8	1	(4)+6	1
P. orientalis	22	M	(3)+4-6	3-5	(3)+5	4
P. brevirostris	2	M	(4)+5	2		
P. stylirostris	4	M	(4)+4	2-4	(4)+4	4
P. vannamei	2	M	(5)+3-4	2		
Parahaliporus sibogae	41	S	(1)+5-8	1-3	(1)+6	2
Hymenopenaeus aequalis	2	S	(2)+7		(2)+7	
H. lucassii	13	S	(4)+2-3		(4)+3	
Solenocera brevipes	20	S	(2-3)+2-3		(3)+3	
S. pectinulata	1	S	(3)+4			
S. faxoni	3	S	(3-4)+3		(3)+3	
S. subnuda	7	S	(3-4)+4-6		(3)+6	
S. prominentis	8	S	(3-4)+4-6		(3)+5	
S. alticarinata	1	S	(4)+5			
S. depressa	5	S	(3-4)+4-6		(4)+4	
Trachypenaeus asper	3	M	(1)+7		(1)+7	
T. curvirostris	105	M	(1)+5-7		(1)+5	
Atypopenaeus compressipes	29	S	(2)+4-6		(2)+5	
Metapenaeus monoceros	50	M	(2)+4-8		(2)+6	
M. intermedius	4	M	(1)+9-10		(1)+9	
M. affinis	128	M	(2)+5-7		(2)+6	
M. joyneri	44	M	(2)+4-7		(2)+6	
M. brevicornis	14	M	(3-4)+2-4		(3)+3	
M. tenuipes	1	M	(3)+3			
M. lysianassa	3	S	(4)+2		(4)+2	

M. spinulatus	3	M	(3)+4-5		(3)+4	
Penaeopsis rectactus	23	M	(1)+9-12		(1)+10	
Parapenaeus fissurus	16	M	(2)+4-6		(2)+5	
P. sextuberculatus	5	M	(2)+4-5		(2)+5	
P. lanceolatus	5	M	(2)+4-5		(2)+5	
P. investigatoris	3	M	(2)+5		(2)+5	
Parapenaeopsis tenellus	44	M	(1)+6-7		(1)+7	
P. cornutus	7	M	(1)+6-7		(1)+7	
P. gracillima	3	M	(1)+4		(1)+4	
P. hungerfordi	3	M	(1)+6-7		(1)+7	
P. maxillipedo	1	M	(1)+6			
P. sculptilis	5	M	(1)+7-8		(1)+8	
P. cultrirostris	4	M	(1)+6-7		(1)+7	
P. hardwickii	26	L	(1)+7-9		(1)+9	
Metapenaeopsis barbatus	129	M	(1)+6-7		(1)+7	
M. acclivis	57	M	(1)+6-7		(1)+6	
M. durus	6	M	(1)+8-9		(1)+8	
M. dalei	53	M	(1)+5-8		(1)+6	
M. incomptus	1	M	(1)+5			
M. coniger	13	M	(1)+6-8		(1)+7	
M. latus	3	M	(1)+7		(1)+7	
M. lamellatus	21	M	(4-5)+4-6		(4)+5	
Trachypenaeopsis richtersii	3	S	(1)+5-6		(1)+5	
Eusicyonia cristata	36	M	(4)+3+3	1	(4)+3+3	1
E. lancifer japonica	11	M	(6)+3-4+2-3	1	(6)+3+2	1
E. curvirostris	4	M	(2)+6	1		
E. inflèxa	8	M	(2)+2+2-3		(2)+2+3	
E. truncata	2	M	(2)+6+2			
E. vitulans	1	M	(4)+2+3			
E. nebulosa	2	M	(2)+7			

B. CARAPACE

a. Terminology for carapace

Since H. MILNE-EDWARDS (1851)* many authorities, such as STIMPSON (1860), BOAS (1880) (cf. CALMAN, 1909), BATE (1888), BOUVIER (1908), PESTA (1918), and SCHMITT (1921), have contributed to terninology of the elements occurring on the carapece. Some elements, however, have been variously termed as noted later on, and some are left untermed yet.

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* original inaccessible to the present author.

In the present paper, the terminology given by BOUVIER (1908) except postocular (DE MAN, 1922), adrostral and median grooves (BURKENROAD) 1934 a), is adopted and illustrated in Fig. 2. Newly termed in this paper are antehepatic and supra-hepatic spines, both of which are also depicted in the same figure.

The ante-hepatic spine is inserted at about middle between the antennal and hepatic spines. The supra-hepatic spine is situated on cervical carina above the hepatic spine. The interpretation for the

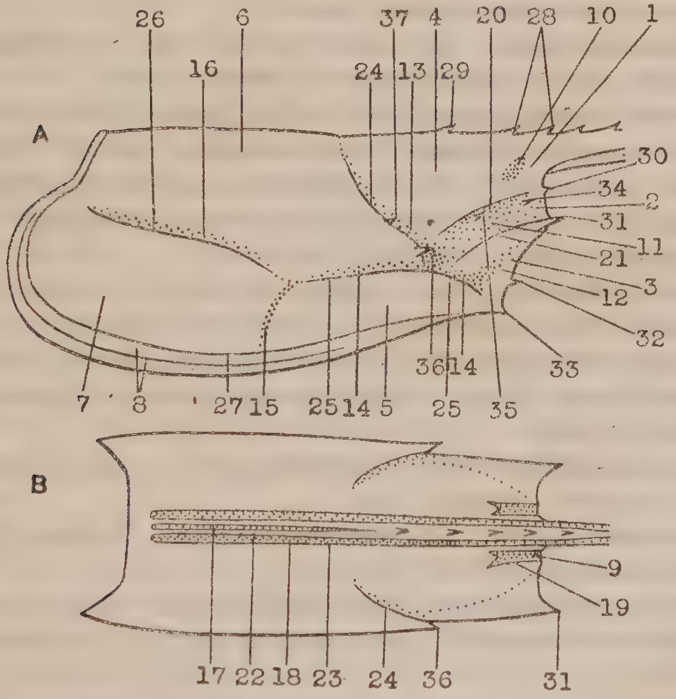

Fig. 2. Schematic representations of carapace for interpretation of carapacial elements. Upper, lateral view; lower dorsal view. Regions: (1) frontal; (2) orbital; (3) antennal; (4) gastric; (5) pterygostomian, (6) cardiac; (7) branchial; (8) marginal. Crooves: (9) gastro-frontal; (10) post-ocular; (11) orbito-antennal; (12) antennal; (13) cervical; (14) hepatic; (15) inferior; (16) branchio-cardiac; (17) median; (18) adrostral. Carinae: (19) gastro-frontal; (20) gastro-orbital; (21) antennal; (22) post-rostral; (23) adrostral; (24) cervical; (25) hepatic; (26) branchio-cardiac; (27) pterygostomian. Spines: (28) post-rostral; (29) epigastric; (30) supraorcital; (31) antennal; (32) branchiostegal; (33) pterygostomian; (34) post-orbital; (35) post-antennal; (36) hepatic; (37) supra-hepatic.

groove and carina lying between the hepatic spine and pterygostomian or branchiostegal edge has been in confusion. Some authors regarded these groove and carina as inferior part of cervical groove and carina and some ones as anterior part of the hepatic. In this account, these may be referred to the latter, inasmnch as these are so far as the present investigation goes, continuous to the hepatic groove and carina respectively just below the hepatic spine.

Synonyma for the annexed terms are as follows: adrostral, gastro-frontal, and orbito-antennal grooves, adrostral, antennal, gastro-frontal, gastro-orbital, and post-rostral carinae, pterygostomian angle, antennal, pterygostomian, and supra-orbital spines.

1. Adrostral groove: the groove on either side of rostrum (ALCOCK, 1906); lateral rostral groove (SCHMITT, 1926).
2. Gastro-frontal groove: post-ocular groove (KUBO, 1942).
3. Orbito-antennal groove: post-antennular sulcus (ALCOCK, 1906).
4. Adrostral carina: lateral rostral carina (BOONE, 1935).
5. Antennal carina: post-antennular crest (ALCOCK, 1906) post-antennal carina. (DE MAN, 1911).
6. Gastro-frontal carina: post-ocular ridge (SCHMITT, 1926; DE MAN, 1911); post-ocular crest (BURKENROAD, 1934).
7. Gastro-orbital carina: post-orbital crest (ALCOCK, 1906).
8. Post-rostral carina: dorsal median carina of carapece (KISHINOUYE, 1900).
9. Pterygostomian angle: antero-lateral (or antero-inferior) angle of carapace (ALCOCK, 1906).
10. Antennal spine: post-antennular spine (ALCOCK, 1906); 1st antennal spine (BATE, 1888).
11. Pterygostomian spine: branchiostegal spine (ALCOCK, 1906).
12. Supra-orbital spine: post-ocular spine (ALCOCK, 1906; DE MAN, 1911).

b. General feature of carapace

The carapace, which affords significant traits for the taxonomy of this family, is well developed with many spines, grooves, carinae and sutures. It exhibits super-specific variation in shape throughout the family, but the following five types, viz., A_1–A_5 with 11 subdivisions: A_{1a}–A_{1d}. A_{2e} and A_{2f}; A_{3g} and A_{3h}; and A_{5i}–A_{5k}, may be recognized.

Type–A_1: Carapace simple in general aspect: Sutures absent altogether. Grooves less developed. Post-ocular groove present or absent. Cervical groove not reaching to dorsum. Gastrofrontal lacking. Post-rostral carina usually extends to about middle of carapace, sometimes reaches to distal margin of carapace. Gastro-orbital carina entirely absent. Antennal not sharply defined. Cervical rather or hardly marked. Hepatic usually not recognizable, sometimes defined anteriorly alone. Branchiocardiac hardly marked. Antennal spine present but hepatic, supra-orbital, branchiostegal and pterygostomian ones present or absent.

Miyadiella, Metapenaeopsis, Metapenaeus, Aristaeomorpha, Aristaeus, and *Penaeopsis* belong to this type. Further, this type is divisible into four subdivisions, *i. e.*, A_{1a}–A_{1d}.

Subdivision–A_{1a}: carapace smooth. Hepatic and antennal spines distinctly present but supra-orbital hardly developed. Pterygostomian angle nearly rounded. Post-rostral carina rather defined, extending to about middle of carapace. Represented by *Miyadiella* only.

Subdivision–A_{1b}: uniformly setose. Orbito-antennal, postocular, and hepatic grooves rather defined. Supra-orbital, hepatic, antennal, and pterygostomian spines present. The hindmost post-rostral spine usually more distant from the penult than the penult from the antepenult. Stridulating organs, lying posteriorly in branchial region, present or absent. *Metapenaeopsis* belongs to this subdivision.

Subdivision–A_{1c}: carapace with many irregular depressed setose areas or glabrous. Post-ocular, orbito-antennal, cervical, hepatic, and branchio-cardiac grooves marked. Antennal carina rather defined. Hepatic one continuous to inferior base of hepatic spine. Supra-orbital, antennal, epigastric and hepatic spines present, the first of which is minute and the remainder are moderate in size, and the last inserted below epigastric spine. Pterygostomian angle rounded. Exemplified by *Metapenaeus.*

Subdivision–A_{1d}: in this type, which involves *Aristaeomorpha foliacea, Aristaeus viliris* and *Penaeopsis rectactus,* carapace uniformly pubescent and rather soft. All the carinae and sulci not conspicuous or absent except anterior about half of post-rostral carina, inferior part of cervical and hepatic ones of *Penaeopsis rectactus,* which are well defined. Antennal, branchiostegal spines present. Supraorbital and pterygostomian ones absent. Hepatic absent in *A. virilis.*

Type–A_2: carapace glabrous, without sutures. Cervical groove reaches about half-way toward dorsum. Hepatic, orbito-antennal, and adrostral grooves developed completely or partly. Gastrofrontal and median ones present or absent. Antennal, gastro-orbital, and hepatic carinae defined, but the second is variable in length. Hepatic and antennal spines present, but branchiostegal absent. Pterygostomian angle not spiniform, with rather rounded edge. Epigastric spine present, always located anterior to middle of carapace.

All species of *Penaeus* belong to this type.

The present type is again referable to two subgroups: A_{2f} and A_{2g}, which entirely correspond to subdivisions 1 and 2 given by BURKENROAD

(1934, pp. 74–75). Subdivision–A_{2f} comprises 9 species: *Penaeus monodon, P. bubulus, P. orientalis, P. penicillatus, P. indicus, P. merguiensis, P. esculentus, P. stylirostris*, and *P. vannamei*, and is characterized by the following respects, viz., adrostral groove does not extend near posterior margin of carapace; and gastro-frontal groove and carina absent. Subdivision–A_{2g}, which includes such five Penaei as *P. japonicus, P. latisulcatus, P. teraoi, P. longistylus*, and *P. brevirostris*, is recognizable in possession of following features: adrostral groove attains near posterior border of carapace; and gastrofrontal groove and carina well developed.

Type–A_3: this type closely resembles the subdivision, A_{1b}, in general aspects. But the principal differences are as follows:—longitudinal suture always present, but transverse one either present or absent, the former of which runs backward from about middle of post-orbital border between supra-orbital spine (or angle) and antennal spine, the latter across branchial region; hepatic groove hardly or rather defined posteriorly; pterygostomian angle narrowly rounded. *Parapenaeus, Parapenaeopsis*, and *Trachypenaeus* may be embraced in the present type.

This type is, however, assorted into two subdivisions: A_{3g} and A_{3h}. In A_{3g}, the carapace is uniformly setose. Transverse suture absent. Longitudinal suture short, reaching to about one-seventh of carapace. Post-ocular groove ill-defined. This subdivision is represented by *Trachypenaeus* only. In A_{3h}, carapace nacked, furnished with both longitudinal and transverse sutures, the former reached to, at least, two-thirds of carapace. Postocular groove not recognizable. *Parapenaeus* and *Parapenaeopsis* are implied in this subdivision.

Type–A_4: carapace usually setose. Grooves and carinae exclusive of post-rostral carina not defined, but sometimes irregular depressions present. Post-rostral carina sharply defined, nearly reaching to posterior margin of carapace, armed with at least more than two prominent teeth. Hepatic spine present without exception. Infra-orbital and pterygostomian angles rather narrowly rounded. *Eusicyonia* belongs to the present type.

Type–A_5: carapace glabrous. Cervical groove and carina well defined, extending to dorsum or nearly so. Hepatic and branchiocardiac grooves and carinae rather or hardly defined. Orbitoantennal groove hardly developed. Post-ocular groove usually absent. Post-rostral carina sharply defined in most cases, extends backward beyond cervical groove, provided with more than two teeth in front of the groove. Antennal and hepatic spines present, but supra-orbital, post-orbital, post-antennal, branchiostegal, and supra-hepatic ones present or absent. Pterygostomian and supra-hepatic ones present or absent. Pterygostomian edge broadly rounded as a whole. *Solenocera*, *Hymenopenaeus*, and *Parahaliporus* are included in this type.

But this type is again splittable into three subdivisions: A_{5i}–A_{5k}. Subdivision–A_{5i} represented by *Parahaliporus sibogae* alone. and characterized as follows: hepatic groove illdefined; suprahepatic, post-antennal, and branchiostegal spines present. Subdivision–A_{5j} involves *Hymenopenaeus*. Hepatic carina defined as conspicuously as cervical one. Branchio-cardiac carina rather or ill-defined. Antennal, hepatic, post-antennal, branchiostegal spines present, the last one inserted more or less behind branchiostegal edge. Subdivision–A_{5k}, embraces *Solenocera*, demarkated with the annexed traits, viz., carapace polished; cervical, hepatic, branchio-cardiac grooves and carinae present, although the third less defined than others. Post-orbital spine present, post-antennal one absent. Branchiostegal spine, if present, projects from branchiostegal border.

c. Some phylogenetical considerations

Little has been known as to phylogenetical evidences for the features of carapace. However, the following facts may not be without interest.

The carapace of Penaeidae is mostly moderate in general configuration, as exemplified by Type–A_{1a}. The carapace of Type–A_{1a} seems not very far from that of ancestral form of Penaeidae judging from metamorphosis of the carapace. Plump condition of the carapace is found in some species of *Metapenaeopsis* and *Eusicyonia*, so far as the present investigation goes. With a view of elucidating specialization of carapacial elements, a comparative study has been made by the writer on metamorphosis* of carapace of *Penaeus japonicus* and *Penaeus bubulus*. In adult form, the carapace of these species is characterized as follows:—gastro-frontal crest is well developed, and adrostral groove nearly reaches to posterior border of carapace in *Penaeus japonicus;* on the other hand, gastro-frontal crest is absent, and adrostral groove extends to about middle of carapace in *Penaeus bubulus*. But the carapace of these species is simple, resembling that of Type–A_{1a} in specimens smaller than about 20 mm long. Whilst that of *P. japonicus* is found decidedly modified when the animal attains about 20 mm in body-length, with adrostral grooves extending beyond middle of the carapace, and when the animal measures ca. 30 mm in body-length, rudiments of the gastro-frontal carinae and the median groove are visible. Then the grooves and carinae get gently developed with advance of age. On the other hand, that of *P. bubulus* remains hardly transformed after passing through such post-larva, which measures about 20 mm in body-length. It is, therefore, evident that the shape of the carapace in *P. bubulus* is primitive. Characteristic to all the species of *Metapenaeopsis*, *Parahaliporus*, and *Eusicyonia*, and to some ones of *Parapenaeopsis*, is the uniformly setose condition of the carapace. Irregular, setose, and depressed areas occur on the carapace of some *Metapenaeus : M. affinis, M. monoceros, M. intermedius* etc. The setae set uniformly on carapace and on the depressed areas become thicker, and the depth and dimension of the depressed areas increase with age at least in *Metapenaeus* given above and it will be treated in detail in the systematic part of this paper.

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* Details of this subject will be given in the systematic part of this paper.

Moreover, the supra-orbital spine is found well developed in post-zoeal and mysis stages. But it gradually decreases in size with advance of age and becomes hardly recognizable later on, as already put on record by HUDINAGA (*op. cit.*) on *Penaeus japonicus* and by PEARSON (1939) on many American species, viz., *Penaeus setiferus, Trachypenaeus constrictus, Parapenaeus longirostris*, and *Eusicyonia stimpsoni*. In adult of *Eusicyonia*, the pterygostomian border is rounded as given elsewhere, but the border of the mysis of *Eusicyonia stimpsoni* is, according to PEARSON (*loc. cit.*), furnished with a spine.

Judging from the facts stated above, the following conclusion may be drawn. The plump aspect of carapace, and presence of carinae, grooves and depressed setose areas, and setae uniformly set on carapace

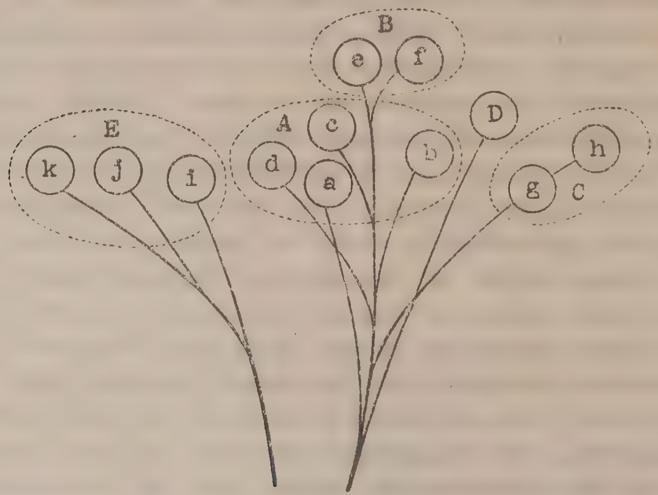

Fig. 3. Phylogenetical relationship of carapace. *A*, type-A_1 group; *B*, type-A_2 group; *C*, type-A_3 group; *D*, type-A_4; *E*, type-A_5 group. *a-d*, types, A_{1a}-A_{1d}; *e* and *f*, types, A_{2e} and A_{2f}; *g* and *h*, types, A_{3g} and A_{3h}; *i-k*, types, A_{5i}-A_{5k}.

may be taken positively specialized. Conversely the presence of the supra-orbital and pterygostomian spines may be interpreted as primitive features. Besides these, the presence of sutures, peculiar to *Parapenaeus, Parapenaeopsis* and *Trachypenaeus*, is apparently a specialization.

At present, no more knowledge of the phyletic relationship of the carapace is available than that given above. Yet the carapace may be, at any rate, genealogically arranged as exhibited in Fig. 3 which is mostly based on the aforementioned morphological resemblances. Thus it appears natural to set up two stems of genealogical tree, *i. e.*, I and II. The characteristics common to all the groups of the Stem-I which comprises four groups, Types, A_1–A_4, are that the cervical groove is not extended to back of carapace, and that the post-orbital; postantennal, and supra-hepatic spines are absent altogether. Whilst those, which are common to all the groups belonging to the Stem-II, which is represented by types, A_{5i}–A_{5k}, are that the cervical groove attains the dorsum or almost reaches to it, and at least a spine among the post-orbital, post-antennal, and supra-orbital ones is found to exist.

Among four types, A_1–A_4, which are involved within stem–I, Type–A_1 appears to be the most primitive. Types, A_2 and A_3 are more closely related to Type–A_1 than to Type–A_4 in general feature. Type–A_2 is specialized in possession of more developed adrostral, median, and gastro-frontal grooves and hepatic, cervical, and gastro-orbital carinae. Type–A_3 is greatly remote from Types–A_1 and A_2 since it has sutures. Type–A_4 is allied to Type–A_1 especially to Subdivision–A_{1b}, in general aspect, but greatly differs from Type–A_1, inasmuch as lacking the antennal spine. Type–A_5 is represented by three subdivisions, A_{5i}–A_{5k}. A_{5j} is nearer to A_{5k} than to A_{5i}, having well defined hepatic carina and no supra-hepatic spine.

The following key is intended to indicate the phyletic relationship among the groups and subgroups :—

- A_1 Cervical groove reaches to about half-way toward dorsum
  - B_1 Antennal spine present
    - C_1 Sutures running longitudinally and transversely absent
      - D_1 Gastro-orbital carina, gastro-frontal one, orbito-antennal and gastro-frontal grooves not developed at all; cervical, hepatic and branchiocardiac carinae and grooves usually rather defined; branchiostegal and pterygostomian spines present or absent ....Type-A.
        - E_1 Pterygostomian spine absent (or anterolateral angle not spiniform)
          - F_1 Branchiostegal spine absent
            - G_1 Cervical, hepatic, branchiocardiac and antennal carinae obscure; antegastric groove absent; antennal spine very minute Sahdivision A_{1a} (*Miyadiella*)

G$_2$ Cervical, hepatic, branchio-cardiac and antennal carinae partly defined; postocular groove well marked; antennal spine moderate ....Subdivision-A_{1b}
(*Metapenaeus*, *Atypopenaeus*)

F$_2$ Branchiostegal spine present; cervical, hepatic, antennal and branchio-cardiac carinae usually obscure, but sometimes well defined; post-ocular groove absent; outer surface setose ....Subdivision-A_{1c}
(*Aristaeomorpha*, *Aristaeus* and *Penaeopsis*)

E$_2$ Pterygostomian spine present (or anterolateral angle spiniform); all carinae and sulci obscure; outer surface setose........Subdivision-A_{1d}
(*Metapenaeopsis*)

D$_2$ Gastro-orbital carina well defined partly or entirely, gastro-frontal one present or absent, antennal one always well marked, hepatic one usually defined (partly or almost entirely); gastro-frontal and median grooves present or absent, adrostral ones sometimes nearly reach posterior margin of carapace, and orbitoantennal one usually well developed; branchiostegal and pterygostomian spines absent ....Type-A_2

H$_1$ Gastro-frontal carine and groove absent, median groove ahsent and adrostral one does not extend to near posterior margin of carapace ....Subdivision A_{2e}
(*Penaeus monodon*-group)

H$_2$ Gastro-frontal carina and groove present, median one present and adrostral one nearly reaches posterior rim of carapace ....Subdivision A_{2f}
(*Penaeus japonicus*-group)

C$_2$ Sutures lying longitudinally and transversely present

I$_1$ Transverse suture only present ....Subdision-A_{3g}
(*Trachypenaeus*)

I$_2$ Both transverse and longitudinal sutures present ....Subdivision-A_{3h}
(*Parapenaeus* and *Parapenaeopsis*)

B$_2$ Antennal spine absent, all sulci and carinae obscure ....Subdivision-A_4
(*Eusicyonia*)

A$_2$ Cervical groove attains to dorsum or nearly reaching to ....Type-A_5

J$_1$ Suprahepatic spine present; hepatic carina obscure ....Subdivision-A_{5j}
(*Parahaliporus*)

J$_2$ Suprahepatic spine absent; hepatic carina defined

K$_1$ Postantennal spine present, and postocular one absent; branchiostegal spine present andit stands somewhat behind branchiostegal margin ....Subdivision A_{5k}
(*Hymonopenaeus*)

K$_2$ Postantennal spine absent and postocular one present; branchiostegal spine, if present, arises from branchiostogal margin ....Subdivision-A_{5l}
(*Solenocera*)

C. TELSON

a. General feature

In adult form, so far as the writer's knowledge is concerned, the telson of the animals included in the present family is regularly tapering into sharply pointed or narrowly truncate tip, provided with a longitudinal sulcus running along dorso-median line, and with or without spines on each dorso-lateral margin. In detail, telson displays, however, remarkable modification throughout all the forms dealt with, although the modification is supergeneric in most cases, and sometimes superspecific. Individual and sexual modifications are less salient. At any rate, the organ of Penaeidae may be referable to the following four morphological categories, viz., Types, B_1–B_4. mostly basing on the condition of dorso-lateral armatures.

Type–B_1: Telson is armed with mobile dorso-lateral spines or spinules alone, typically with two–four pairs of movable ones in distal half (Fig. 4, *A*) The following genera and species are refarable to this type, viz., *Aristaeus, Aristaeomorpha, Trachypenaeus, Penaeus japanicus, P. teraoi, P. longistylus, P. latisulcatus Metapenaeus intermedius,* and *M. spinulatus.*

Type–B_2: In this type, telson carries a pair of immovable dorso-lateral spines which are preceded by a series of movable ones. All the spines are as a whole much larger in size than those of the Type–B_1. The dorso-median groove disappears near base of the last pair of spines (Fig. 4, *B*). The present type is represented by *Metapenaeopsis, Penaeopsis Trachypenaeopsis* and a peculiar form, *Eusicyonia inflexa.*

Type–B_3; Telson of this type is characterized in possession of a pair of subterminal fixed spines which are smaller than fixed ones of Type–B_2 (Fig. 4, *C*). *Solenocera, Hymenopenaeus, Parahaliporus, Parapenaeus,* and *Eusicyonia* except *E. inflexa,* are attributed to this type.

Type–B_4: Telson bears no dorso-lateral spines whatever (Fig. 4. *D*). This type is exemplified by *Miyadiella, Atypopenaeus,* and most species of *Penaeus* and *Metapenaeus: P. bubulus, P. monodon, P. orientalis, P. indicus, P. merguiensis, P. penicillatus, P. esculentus P. vannamei, P. stylirostris, P. brevirostris, M. monoceros M. affinis,* and *M. joyneri.*

b. Metamorphosis of telson of *Penaeus bubulus*, and some phylogenetical considerations.

Metamorphosis: In regard to metamorphosis of telson of Penaeids, our knowledge is very meagre. It has been studied by OSADA, TANIZAKI, and NAKAZAWA (1936), and HUDINAGA (1942) on *Penaeus japonicus,* in which the telson belongs to Type–B_1. In the present investigation, the metamorphosis has been traced on *Penaeus bubulus*, in which the telson is of Type–B_4, dealing with a series of specimens from post-larval stage to adult one, which were cultured at Taiwan (Formosa) Fisheries Experimental Station and kindly placed at the writer's disposal through the courtesy of Mr. T. Aoki of the Station. The transformation of the telson is observed as follows:—

In a post-larval specimen, 9.0 mm in body-length, the telson is subrectangular in outline, but gradully diminishes its width toward tip (Fig. 4, *E*). The proportion against the breadth measured between antero-lateral angles is ca. 4.2 in total length measured along median line, and ca. 0.4 in the width between the postero-lateral angles. The dorso-lateral margins armed with three pairs of setae, of which the first pair is situated at about six-seventeenths, the second at ten-seventeenths and the third at fourteen-seventeenths. The distal margin is convex, fringed with five pairs of bristles. Of the bristles, each outermost one is attached to each postero-lateral corner, about twice in size compared with the intermediate ones which are subequal in size, and are about one-seventeenth the length of telson.

In passing into a stage measuring 11 mm in body-length, the telson undergoes some proportional changes, viz;, the ratio to breadth measured in the proximal widest region is about 5 in total length of telson, and about 0.5 in the width measured between postero-lateral angles. The first, second, and third pairs of the dorso-lateral armatures are located at about three-, five-, and seven-ninths respectively. The fundament of the dorsomedian groove firstly appears. But the terminal border is still rounded (Fig. 4, *F*).

The telson, when the animal attains a length of 11.8 mm, exhibits a transitional condition in general aspect as seen in Fig. 4, *G*. It becomes proximally wider and distally narrower than that of the preceding two stages. The proportion to the width measured proximally 4 in the length from base to tip, 0.32 in the width between disto-lateral angles. All the dorso-lateral setae shift rearwards in accordance with growth, so that, these setae are found inserted at two-, three- and four-fifths of the length respectively. The dorso-median sulcus becomes more pronounced. But the most remarkable change takes place at the tip, viz, the tip gets sharply pointed, and the intermediate four pairs of setae set along distal border appear very reduced in size.

In passing through stages measuring from 11.8 mm to 15.5 mm in body-length, the organ undergoes a remarkable modification in general feature. At the time, the prawn reaches a body-length of 15.5 mm, telson is of elongated triangle in upper aspect, and about three times as long as wide measured in the widest region. The intermediate setae set on the distal border are absent, but the seta located on each postero-lateral angle still persists as fourth pair of the dorso-lateral armatures. The tip of telson so lengthens posteriorly as far beyond the extremity of the last pair of dorsolateral bristles. The relative position of the anterior three pairs of dorso-lateral spines is nearly the same as in the stage, 11.5 mm long.

In a specimen, 25mm long, the telson is provided with the lateral spines greatly diminished in size (Fig. 4, *I*), and at least in such a specimen as 33mm in body-length, the lateral armatures disappear at all. Thus it almost assumes its adult form (Fig. 4, *J*).

From the facts given above, it may be mentioned that telson of *Penaeus bubulus* reaches to its adult from passing through, at least, four distinct stages afterward post-larval stage. The first stage appears when the animal measures 9–11 mm long, In this stage the telson is very similar to that of Atyid shrimps in general feature, thus this stage

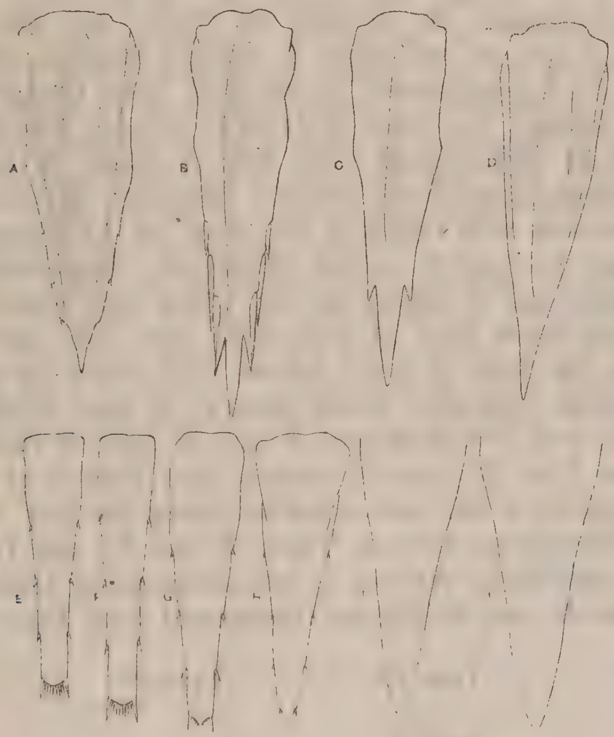

Fig. 4. Four types of telson (*A–D*), and metamorphosis of telson of *Penaeus bubulus* (*E–J*). *A*, Type-B_1, *Trachypenaeus curvirostris*, 73 mm in body-length; *B*, Type-B_2, *Metapenaeopsis barbatus*, 40 mm; *C*, Type-B_3, *Parapenaeus lanceolatus*, 71.4 mm; *D*, Type-B_4, *Metapenaeus affinis*, 95 mm; *E*, 9 mm; *F*, 11mm; *G* 11.8 mm; *H*, 15.5 mm; *I*, 25 mm; *J*, 33 mm. *A–D*, ×4.8; *E–G*, ×28; *H*, ×20; *I* and *J*, ×16.

may be provisionally called "Atyid stage". The second stage appears when the animal attains a length, 11.8 mm long, the apparatus is very similar to that of Palaemonoid shrimps and prawns, hence "Palaemonoid stage", In the third when the animal reaches to 15.5 mm in body-length, the telson resembles the Type–B_1. Moreover, the telson of the third stage transforms to its adult form, which is of Type–B_4, lacking its dorso-lateral armatures at the time the animal measures about 25mm in body-length. The process of the metamorphosis from the Palaemonoid type to the Type–B_1 is identical whatever as is the case with *Penaeus japonicus* (OSADA and others. *op. cit.*, p. 22, fig. 5; and HUDINAGA, *op. cit.* p. 352, fig. 28), and *Leander japonicus*, *L. carinatus* (KUBO, 1943, pp. 18, 23, 62, figs, 14, *J* and *K*), and *L. styliferus* (KEMP, 1917, p. 216).

Phylogenetical consideration: it is generally known that the telson of Penaeids is Y-shaped in outline in zoea-stage, symmetrically bifurcate at apex in mysis-stage. As revealed by OSADA and others (*loc. cit*), and HUDINAGA (*loc. cit*), the telson of *Penaeus japonicus*, which belongs to the Type–B_1, is transformed to its adult form through Atyid and Palaemonoid stages. The telson of *Penaeus bubulus*, which is of Type–B_4, passes Atyid-, Palaemonoid-, and Type–B_1–stages in the course of its metamorphosis as set forth already. Moreover, BURKENROAD (1934 a. p. 120) mentions with regard to the telson of *Eusicyonia*, in which telson belongs to Type–B_3 except *Eusicyonia longicauda* (RATHBUN) (STEBBING, 1914) and *E. inflexa* sp. nov. which have telson referable to Type–B_2, "post-mysis stage of *Eusicyonia* have four pairs of mobile lateral spines, the distal of which become fixed, while one of the mobile pairs may persist even after sexual maturity in some species".

From the facts aforementioned, it may be inferred that Type–B_2 is modified from Type–B_1, Type–B_3 changes from Type–B_2 at least in some Penaeids; Type–B_1 is the most primitive among the four types. B_1–B_4, Type–B_2 is intermediate between Types, B_1 and B_3, and Type–B_4 is the most highly specalized. As seen in metamorphosis of telson of *Penaeus bubulus*, Type–B_4 may be directly transformed from Type–B_1.

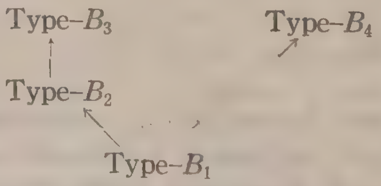

Fig. 5. Phylogenetical relationship of telson of Penaeidae.

Conclusively one may accept the phylogenetical relationship of this item as follows: –there are two branches diverging from Type–B_1, on one branch with Type-B_2 and Type-B_3, and on the other with Type-B_4 (Fig. 5).

D. OPHTHALMOPODA

This organ consists without exception of three segments. of which the basal two joints are always subequal in size, whilst the last one is thickened, much larger than other ones, and crowned somewhat anterolaterally by well pigmented cornea. In relation to the general configuration of this appendage, the following three types may be distinguished, viz., Types-C_1–C_3.

Type-C_1: This type is represented by the Penaeids of *Aristaeus* and *Aristaeomorpha*. Basal two segments are comparatively small and simple, bearing neither protuberance nor spine altogether. The last article is rather elongated, somewhat pear-shaped in outline, carrying subspherical ophthalmus. The peduncular portion of this article, in upper aspect, is subtrapezoidal, diminishing in width posteriorly. In outer view it is subrectangular in outline, and its anterior portion is strongly protruded to the corneal region. Sometimes, as in *Aristaeus*, a small round-topped protuberance, which is regarded as a short of ocellus and homologous with that of *Benthesicymus* and *Gennadas* (BATE, 1888, XVII), exists on inner surface immediately behind the cornea. Cornea is considerably wider than stalk.

Type-C_2: This type is exemplified by all other species dealt with except the Penaeids belonging to *Aristaeus*, *Aristaeomorpha*, and *Miyadiella*. Basal two segments are thicker, and the corneal segment shorter than those of Type-C_1. First segment has a projection directed anteriorly closs to distomedian angle. The projection is depressed, with

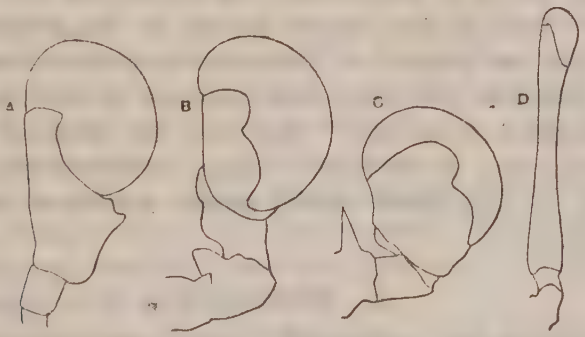

Fig. 6. Three types of eye in upper aspect. *A*, Type-C_1, *Aristaeus virilis*, ×6; *B*, Type-C_2, *Penaeus latisulcatus*, ×7.5; *C*, Type-C_2, *Eusicyonia lancifer japonica*, ×7.5; *D*, Type C_3, *Miyadiella pedunculata*, ×15.

rounded apex in Penaeinae excluding *Miyadiella*, but that of *Eusicyoninae* is spiniform, sharply pointed at apex. Corneal segment (including cornea) is somewhat longer than wide, corneal stalk dorsally rather broad and flattish, with a minute notch at about middle of outer border, and ventrally narrow and somewhat convex. Cornea is greatly wider than stalk (Fig. 6, *B* and *C*).

Type-C_3: This type is confined to *Miyadiella* only. Basal two segments are similar to those of Type-C_1 in general feature. Corneal joint is astonishingly elongated, bar-shaped, gradually decreasing in size toward middle, about 12 times as long as wide measured at half-way, without a notch on distolateral border. Cornea is a little wider than stalk (Fig. 6, *D*).

Remarks: As given above, Type-C_2 is the most generalized one among the three, and Type-C_1 is probably characteristic to Aristaeinae. Besides such supergeneric modification, general configuration of this organ undergoes considerable interspecific modification but no individual and sexual ones.

It has been generally believed to be diagnostic to Eusicyoninae that the basal segment has a shinous projection on the disto-median border. But it should be noticed in this place that the segment of Solenocerinae and Penaeinae exclusive of *Miyadiella* has a protuberance which is less calcified, depressed, and rounded at apex as noted above, and is probably homolgous with the spinous projection of Eusicyoninae. Thus the presence or absence of the armature gives no criterion for the demarkation between Eusicyoninae and others except Aristaeinae and *Miyadiella*.

The corneal joint of Type-C_3, characteristic to *Miyadiella pedunculata* only, stands far apart from that of other two types in general feature. From the phylogenetical point of view, it is of interest that the segment is very similar to that of *Acetes* (KISHINOUYE, 1905, p. 163) and *Sicyonella* (BORRADAILE, 1910, p. 259) which belong to Sergestidae. But only difference is that the segment of *Miyadiella* is gently constricted toward middle, with proximal and distal ends subequal in size, instead of being strikingly elongated fig-shaped. Moreover, the segment of *Myadiella* closely resembles that of *Ogyrides* (= *Ogyris*) (KEMP, 1915, p. 284; and YOKOYA, 1927, p. 171), which inhabit muddy bottom of shallow waters like *Miyadiella*.

E. ANTENNULE

Antennule invariably consists of a stout peduncle and two flagella. The peduncle is made up of three segments. First segment is longest, about half or more the length of the peduncle, strongly depressed, subrectangular in outline, dorsally excavated to a considerable degree for reception of eye, typically provided with stylocerite, a small spine on disto-laterale, angle, prosartema and a spine (on ventro-median border near anterior end) or "Parapenaeid spine". Stylocerite is variable in length, usually attains about middle of basal antennular segment, but reaches to or beyond distal border of basal antennular segment in some *Penaeus* and all of *Metapenaeopsis*. Prosartema is well developed in Penaeinae and Solenocerinae, but very vestigial and seen as a minute pointed boss or completely absent in Aristaeinae and Eusicyoninae. The so-called "Parapenaeid spine", a primitive feature, as it occurs in mysis stage of all Penaeids (BURKENROAD, 1934 b, pp. 8-9), is found to persist in *Penaeopsis Metapenaeopsis* and *Parapenaeus*. It is, however, well developed in *Penaeopsis rectactus*, *Metapenaeopsis coniger* and *M. latus*, and very rudimentary in all species of *Parapenaeus* and most ones of *Metapenaeopsis*. The second segment is much shorter than the first, and longer than the third, usually subcylindrical, sometimes more or less expanded sidewise and flattish on ventral surface, but always devoid of any spine or projection. The third is shortest, sometimes shorter than wide, furnished with two flagella at apex in most cases. The flagella are also very variable throughout all the Penaeids examined in the following respects: length, shape, and position of insertion.

Length: Flagella are as a rule shorter than carapace or even less than half the length of the peduncle in Penaeinae and Eusicyoninae except *Miyadiella pedunculata*, *Parapenaeopsis gracillima*, and *Metapenaeopsis coniger*; as long as or somewhat longer than carapace in *Solenocera* and some species of *Hymenopenaeus*; strikingly longer than body in Aristaeinae, and some Solenocerinae, *e. g.*, *Parahaliporus sibogae*. But in Aristaeinae the upper or outer flagellum is very vestigial and short.

Shape: Both flagella are cylindrical or subcylindrical in *Hymenopenaeus*, *Parahaliporus*, *Eusicyonia*, other genera of Penaeinae except *Penaeus*, in which one of the ramus is proximally compressed. Both ones are compressed, narrow, ribbon-like in outline, upper one flattish and the other concavo-convex with convex surface outward in *Solenocera*. Inner or lower ramus is cylindrical, and the outer extremily short and foliaceous in *Aristaeus* and *Aristaeomorpha*.

Position of insertion: Both flagella are attached to apex of the stalk in Penaeinae, Solenocerinae, and Eusicyoninae. Whilst the inner one is inserted at tip, and the outer near proximal upper border of the last peduncular segment in Aristaeinae.

Sexual modification is not recognizable in the peduncle, but rather salient in the flagella. The flagella are usually longer, sometimes armed with spinules (as in *Penaeus vannamei*, *P. stylirostris* and *Metapenaeopsis coniger*) in male.

Summarizing the facts given above, especially taking presence or absence of prosartema and "Parapenaeid spine", shape and position of insertion of the flagella into consideration, the apparatus is referable into the following five morphological categories: Type-D_1–D_5, which are defined as follows:—

- A_1 Prosartema well-developed
  - B_1 Both antennular flagella cylindrical or one of which proximally flattish
    - C_1 Parapenaeid spine present ....Type-D_1 (*Metapenaeopsis*, *Penaeopsis*, and *Parapenaeus*)
    - C_2 Parapenaeid spine absent ....Type-D_2 (*Penaeus*, *Metapenaeus*, *Trachypenaeus*, *Trachypenaeopsis*, *Parapenaeopsis*, *Miyadiella*, *Hymenopenaeus*, *Parahaliporus*, and *Atypopenaeus*)
  - B_2 Both antennular flagella compressed, narrow ribbon-like, prosartema present, Parapenaeid spine absent ....Type-D_3 (*Solenocera*)
- A_2 Prosartema very vestigial
  - D_1 Both antennular flagella much shorter than carapace, inserted at apex of the peduncle ....Type-D_4 (*Eusicyonia*)
  - D_2 Upper antennular flagellum very short, foliaceous, inserted near posterior dorsal edge; lower one longer than body, cylindrical, attached to apex of the peduncle ....Type D_5 (*Aristeaus* and *Aristeaomorpha*)

F. MOUTH-PARTS

a. General feature

Mandible. Mandible well developed, composed of well calcified molar and inciser processes and an endopodite. The molar process flattish or somewhat indent, suboval or subrectangular on masticatory surface, pointed at postero-median angle of masticatory edge in most cases. The incisor one is rather thin, produced antero-ventrally from basal outer surface of molar process, and separated from the molar one by a rather deep triangular depression; cutting edge is sharply defined, usually provided either with a notch, or with a pointed tooth near anterior acuminate end, but rarely entire. The endopodite is foliaceous and two-jointed, inserted on the surface between anterior bases of the molar and incisor processes. The distal segment is much larger than the proximal in Penaeinae and Eusicyoninae (Figs. 7, and 8, *A–W*). On the other hand, it is much smaller in *Aristaeus*, *Aristaeomorpha*, and *Hymenopenaeus* (Fig. 8, *X–C*). It is peculiar to the first two genera that the palp is comparatively very short and hardly attains the inner base of antennular peduncle (Fig. 14, *F*) instead of reaching to, at least, about middle of the fourth antennal segment (Fig. 14, *B*).

At any rate, three supergeneric types: E_1–E_3, may be recognized mostly based on the general configuration of the palp.

Type-E_1: The palp is rather slender, more or less pediform. Basal segment 2–3 times as long as wide. Distal segment much shorter and narrower than bassal one, narrowly rounded at apex (Fig. 8, *Y–C*).

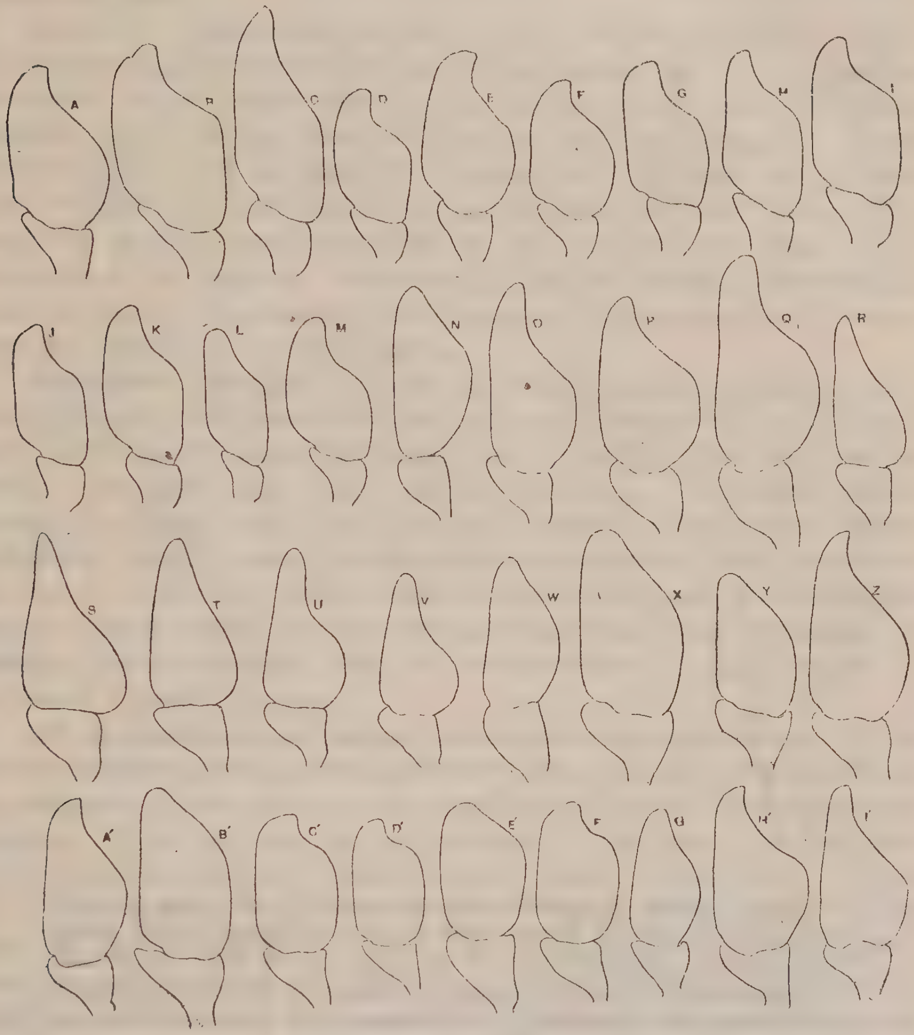

Fig. 7. Outlines of mandibular palps of Type-E_1. A, *Penaeus longistylus*; B, *P. bubulus*.; C, *P. orientalis*; D, *P. monodon*; E, *P. latisulcatus*; F, *P. teraoi*; G, *P. brevirostris*; H, *P. stylirostris*; I, *P. vannamei*; J, *P. penicillatus*; K, *P. indicus*; L, *P. merguiensis*; M, *P. esculentus*; N, *Miyadiella pedunculata*; O, *Metapenaeus intermedius*; P, *M. affinis*; Q, *M. monoceros*; R, *M. tenuipes*; S, *M. joyneri*; T, *M. spinulatus*; U, *M. brevicornis*; V, *M. lysianassa*; W, *Atypopenaeus compressipes*; X, *Parapenaeopsis hardwickii*; Y, *P. cultrirostris*; Z, *P. cornutus*; A′, *P. hungerfordi*; B′, *P. sculptilis*; C′, *Parapenaeus fissurus*; D′, *P. lanceolatus*; E′, *P. investigatoris*; F′, *P. sextuberculatus*; G′, *P. tenellus*; H′, *Trachypenaeus asper*; I, *curvirostris*. A, D, F, G, H, J, K, M, and U, ×2.8; B, ×1.8; C and D, ×2.4; E, I, L and S, ×3.2; N, ×24; P, R, T, X–Z, A′–D′, and F′–I′, ×4.8; Q ×5.6; V, B′ and E′, ×6; W. ×8.4.

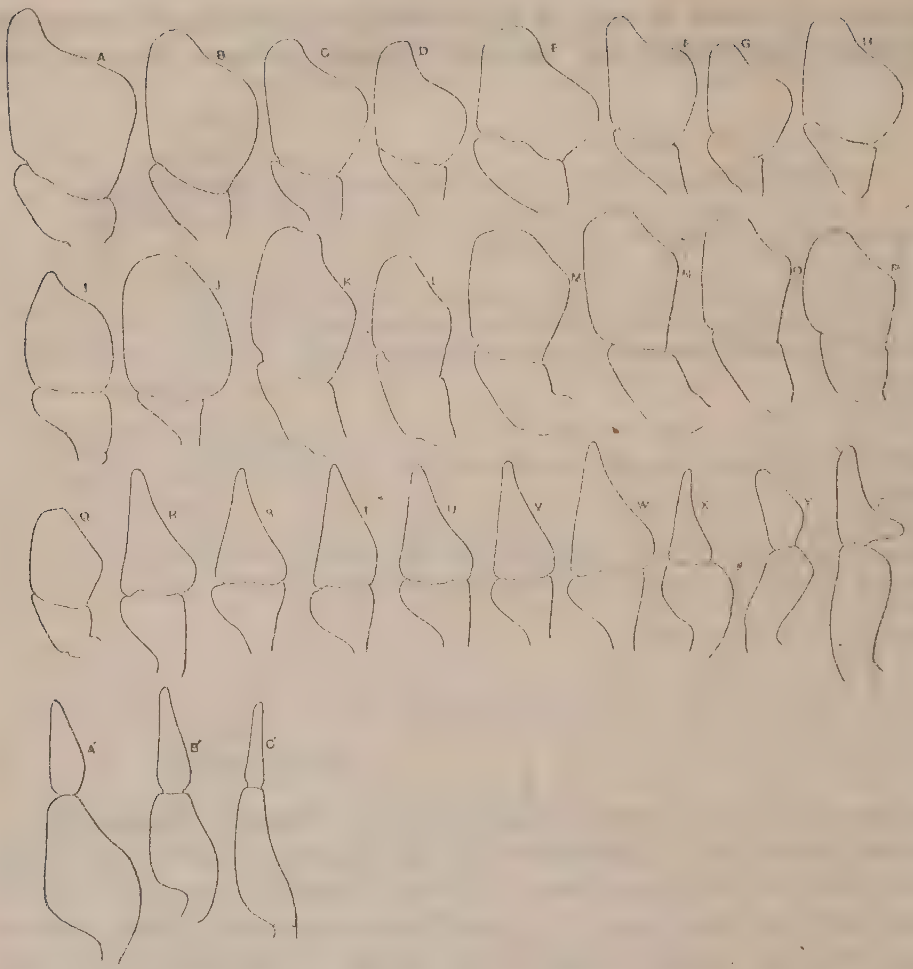

Fig. 8. Outlines of madibular palpe of Type-E_1 (A-Q), Type-E_2 (R-X), and Type-E_3 (Y-C′). A, *Metapenaeopsis durus*, B, *M. barbatus* ; C, *M. acclivis* ; D, *M. incomptus* ; E, *M. lamellatus* ; F, *M. coniger* ; G, *M. latus* ; H, *M. dalei* ; I, *Trachypenaeopsis richtersii* ; J, *Penaeopsis rectactus* ; K, *Eusicyonia curvirostris* ; L, *E. cristata* ; M, *E. truncata* ; N, *E. nebulosa* ; O, *E. inflexa* ; P, *E. lancifer japonica* ; Q, *E. vitulans* ; R, *Solenocera depressa* ; S, *S. pectinulata* ; T, *S. subnuda* ; U, *S. faxoni* ; V, *S. prominentis* ; W, *S. alticarinata* ; X, *S. brevipes* ; Y, *Aristaeus virilis*, Z, *Aristaeomorpha foliacea* ; A′, *Hymenopenaeus aequalis* ; B′, *H. lucasii* : C′, *Parahaliporus sibogae*.
A-E, and H, ×4.8 ; F, G, L, O, R, and A, ×6 ; I, K, M, S, T-Z, B′, and C′, ×8.4 ; J, ×2.8 ; N, ×12 ; P, ×5.6.

Hymenopenaeus, *Parahaliporus*, *Aristaeus*, *Aristaeomorpha* belong to the present type.

Type-E_2: Basal segment is triangular in outline, expanded and thickened distally, as long as wide measured near distal edge. Distal segment is again triangular, somewhat swollen postero-laterally, bluntly pointed at apex, 1.4–1.8 times as long as wide measured at base, 1–2 times the length of the first segment (Fig. 8, *R–X*). Exemplified by *Solenocera* only.

Type–E_3: Basal segment is either of an inverted triangle in outline as in Penaeinae, or subrhombic as in Eusicyoninae, but always gradually thickened toward distal end, and as long as wide measured in the broadest region. Distal segment markedly expanded and lamellar assuming the outline of a fan, broadly excavated on disto-lateral rim in most cases, rounded at apex, about 1–2 times as long as wide. about 1.3–3 times the length of the basal (Figs. 7,8, *A–Q*, and 12, *B*). This type is represented by *Penaeus*, *Metapenaeus*, *Metapenaeopsis*, *Parapenaeus*, *Parapenaeopsis*, *Penaeopsis*, *Trachypenaeus*, *Trachypenaeopsis*, *Atypopenaeus*, *Miyadiella*, and *Eusicyonia*.

Maxillula. Maxillula is made up of three laciniae unequal in size: proximal and distal gnathobasic laciniae and an endopodite. The proximal gnathobasic lacinia is thumb-like in outline, directed inward, distally provided with rather thickly set setae. The distal one is considerably larger than the proximal, widened toward apex, almost straight or slightly convex on disto-median edge which runs parallel to the median axis of the body, rounded at anterior and postero-median angles, distally setose likewise the proximal one. The endopodite is lamellar, usually slenderer than the two gnathobasic laciniae, jointed or unjointed, directed sidewise.

All the morphological matters given above are common to all the species at the writer's disposal. But the general feature and number of the segments of the palp are superspecifically, mostly supergenerically, variable. Thus regarding the configuration of the palp, the maxillula may be assorted into the following three types: Types–F_1–F_3. Type–F_1: The endopodite is not segmented, as long as, or somewhat shorter than, the distal gnathobasic lacinia. This type may be again divided into two subdivisions: F_{1a} and F_{1b}. In subdivision–F_{1a}, the palp is gently diminishing in width toward tip, rounded at apex, about two and half times as long as wide measured at base, provided with a thicket of hairs on each anterior and posterior margins near base and a series of several long setae along anterior subterminal edge (Fig. 9, *A*). In Subdivision–F_{1b}, the palp is rather abruptly pointed at apex, about two-fifths as wide as long measured at base, and has three outgrowths, two on anterior border and one on the other. Of the anterior ones, the proximal one set at a third, fringed with hairs; the distal is smaller than the other, provided with a spinous setae (sometimes two or three). That of the posterior border is similar to and opposite the proximal of the anterior border. (Fig. 9, *B*).

The group of this type implies *Aristaeus*, *Aristaeomorpha*, *Hymenopenaeus*, *Parahaliporus*, *Metapenaeopsis*, *Penaeopsis*, *Miyadiella*, *Trachypenaeus*, *Parapenaeus*, *Solenocera*, and *Eusicyonia*, and first four of which belong to Subdivision–F_{1a}. Besides these, *Parapenaeopsis cultrirostris* is included in Subdivision–F_{1b}.

Type–F_2: The palp of this type is two-jointed, subequal in length to the distal gnathobasic endite. First segment is about 2.5 times as long as wide measured at base, similar to the palp of Subdivision–F_{1b} in having three outgrowths, though the proximal one of anterior border is more prominent than that of Subdivision–F_{1b}. Second is minute, pointed at apex, with sparsely set hairs (Fig. 9, *C*).

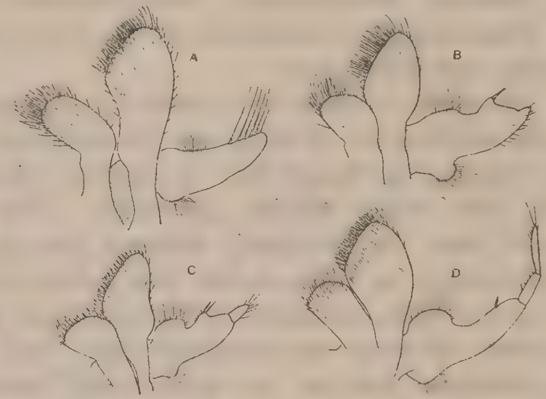

Fig. 9. Maxillula. A, Type-F_{1a}, *Parahaliporus sibogae* (95 mm in body-length), ×8.4; B, Type-F_{1b}, *Trachypenaeus curivrostris* (77 mm), ×8.4; C, Type-F_2, *Metapenaeus joyneri* (113.5mm), ×5.8; D, Type-F_3, *Penaeus orientalis* (157 mm), ×2.4.

Metapenaeus, *Atypopenaeus*, *Trachypenaeopsis* and all other species of *Parapenaeopsis* except *P. curtrirostris*, are embraced in the group of this type. Besides these, *Penaeus merguiensis* and *P. penicillatus* belong to this group.

Type–F_3: The endopodite is slenderer than that of all other types, much longer than the distal gnathobasic endite, consists of three segments, distal two of which are very thin. The basal segment gently narrows toward distal end, more or less curves anteriorly in distal half, furnished with a protuberance like that of Subdivision–F_{1b} and Type–F_2 near base of each anterior and posterior border, and usually has a large seta on anterior subterminal edge. The second segment is about a quarter the length of the first. The third is somewhat longer than the second, pointed at tip (Fig. 9, *D*).

All other species of *Penaeus* excluding the two forms referred to the Type–F_2 form the group of this type.

Maxilla. As shown in Fig. 10, *A*, maxilla is foliaceous made up of proximal and distal gnathobasic endites, endopodite, and exopodite. The gnathobasic endites are distally directed inward, fringed with hairs on median borders, essentially bifid with anterior larger and posterior smaller lobules. Each of the lobule gets gradually larger toward apex. The posterior lobule of the proximal lacinia is, if present, smallest of all, and superspecifically very variable. The endopodite is not jointed, projected a little antero-laterally, extending as far as apex of the anterior lobule of the distal gnathobasic lacinia, has a small pointed appendage on disto-median border, and armed with a thicket of short acute setae near base of the disto-median appendage. The exopodite is inserted close to posterior base of the endopodite, ear-shaped with rounded anterior and posterior edges, fringed with hairs along entire margin.

Three types: G_1–G_3, are recognized basing on the condition of the proximal gnathobasic lacinia.

Type–G_1: The posterior lobule of the proximal gnathobasic lacinia is as large as, or a little smaller than, the anterior lobule of the gnathobasic one (Fig. 10, *A*). This type is represented by the Penaeids of the following genera: *Metapenaeopsis*, *Atypopenaeus*, *Hymenopenaeus*, *Parahaliporus*, *Trachypenaeus*, *Trachypenaeopsis*, *Metapenaeus*, *Parapenaeus*, *Penaeopsis*, *Solenocera*, *Aristeus*, *Aristeomorpha* and *Penaeus* exclusive the annexed four species of *Penaeus*: *Penaeus bubulus*, *P. penicillatus*, *P. stylirostris* and *P. vannamei*.

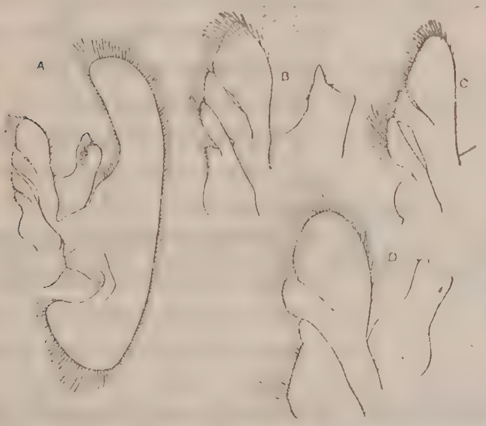

Fig. 10. Three types of maxilla. *A*, Type G_1, *Penaeus japonicus*, ×2.4; *B*, Type G_2, gnathobasic laciniae and endopodite of *Parapenaeopsis cornutus*, ×8.4; *C*, Type G_3, ganthobasic laciniae of *Penaeus vannamei*, ×3.2; *D*, Type G_3, gnathobasic laciniae and endopodite of *Eusicyonia cristata*, ×12.

Type–G_2: The lobule is rudimentary (Fig. 10, *B*). All the species of *Parapenaepsis*, and three of *Penaeus*: *Penaeus bubulus*, *P. penicillatus*, and *P. stylirostris* belong to this type.

Type–G_3: The lobule absent at all (Fig. 10, *C* and *D*). This type is characteristic to all the forms of *Eusicyonia*, and *Penaeus vannamei*.

First maxilliped. First maxilliped is made up of inner posterior and anterior laciniae, an endopodite, and an exopodite. The inner laciniae are setose. The postarior lacinia is divided into two lobules by a median depression, the outer lobule of which has a deep notch near its anterior end. The anterior lacinia is larger than the posterior, somewhat concavo-convex with ventral convex surface, rounded at apex, with nearly straight inner border which lies parallel to the median axis of the body, and with outer border curving medially in distal half. The endopodite arises from anterior base of the inner distal lacinia, slender, segmented or not, proximally compressed and dilated, armed with a small number of stout setae near inner base. The exopodite is foliaceous, posteriorly truncate and rounded at postero-lateral angle in most cases, anteriorly narrowed into a point or suddenly into a slender appendage.

The endopodite and exopodite are supergenerically variable in configuration. and two types: H_1 and H_2, may be recognized.

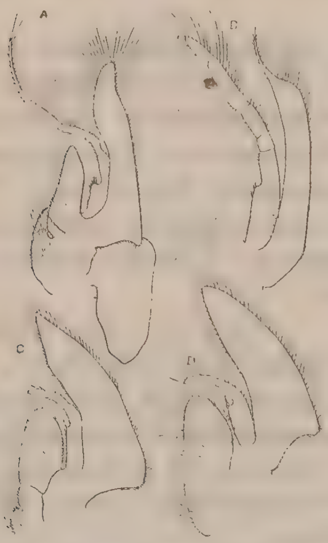

Fig. 11. First maxilliped. *A*, Type-H_{2a}, *Penaeus japonicus*, ×2.4; *B*, Type H_{2b} *Aristaeus virilis*, ×4.8; *C*, Type H_1, *Eusicyonia cristata* (adult), ×6; *D*, *E. cristata* (young, 23 mm in body-length), ×12.

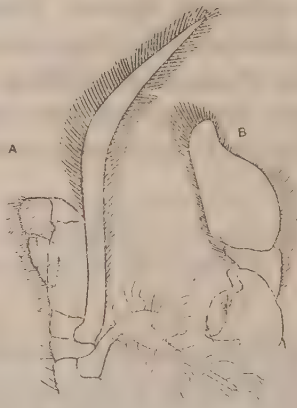

Fig. 12. Second maxilliped (*A*), and mandible (*B*) of *Penaeus japonicus*, ×2.4.

Type-H_1: The endopodite appears less developed, unsegmented, not extending beyond far end of the exopodite (Fig. 11, *C* and *D*). Eusicyoninae belongs to this type.

Type-H_2: The palp stretches beyond tip of the exopodite, and is segmented into five. Exemplified by Penaeinae, Aristaeinae and Solenocerinae. This type is again splittable into two Subdivisions: H_{2a} and H_{2b}. In Subdivision H_{2a} which involves all the Penaeids of Penaeinae and Solenocerinae, the palp is very slender, the apical joint appears much longer than the penult; the exopodite anteriorly narrowed, rounded at apex. (Fig. 11, *A*). In Subdivision–H_{2b} which is peculiar to the prawns of Aristaeinae, the palp is much thicker than that of Subdivision–H_{2a}, the fifth article is much shorter than the fourth, the exopodite distally flagelliform (Fig. 11, *B*).

Second maxilliped. Second maxilliped is pediform, seven-segmented, inverted J-shaped as the carpus is directed medially and the last two joints backward. The basal three joints are shorter than wide. The meropodite is subrectangular in outline, longest of all, medially lamellar. The carpus and propodus are subequal in size and length. The dactylus is somewhat longer than the propodus, narrowed distally, rounded at apex (Fig. 12, *A*), exopodite is attached to the outer base of ischiopodite, well developed, about twice the length of endopodite in Penaeinae and Aristaeinae, rather vestigial, and does not reach to distal end of the meropodite in Solenocerinae, especially very rudimentary in *Parahaliporus*, and entirely absent in *Eusicyoninae*.

Third maxilliped. This appendage departs less from the general form of the thoracic limbs than does the second maxilliped setose, seven-segmented as in the second. The propodus has a thicket of short bristles on the disto-ventral surface irrespective of sex, but less developed in female than in the other. The last article decreases in size toward tip, rounded at apex. The exopodite is flageliform in all other Penaeids dealt with except those belonging to *Parahaliporus* and *Eusicyonia*. It assumes a very rudimentary condition in *Parahaliporus*, absent altogether in *Eusicyonia*.

The characteristics given above except exopodite are common to all the species examined. But this appendage is referable to the following three categories: Type–I_{1-3}, respectively, mostly based on the feature of the distal two segments.

Type–I_1: The last two segments have no appendages except the thicket of short setae, and not sexually dimorphic. The last segment is a little depressed, rounded at apex. shorter than the propodus (Fig. 13, *A*). All other forms dealt with except those of *Penaeus* and *Aristaeus virilis* are referred to this type.

Type–I_2: The propodus is sexually dimorphic: it has a tuft of hairs, reaching about middle of the dactylus, on the disto-dorsal edge in male (Fig. 13, *C*). The dactylus is peculiar: the dorsal edge gently curves ventrally, the ventral suddenly produced downward near proximal and runs straightly forwards (Fig. 13, *C* and *D*). *Aristeaus virilis* only belongs to this type.

Type–I_3: The distal two segments are different with sex, those of female closely resemble those of Type–I_1 (Fig. 13, *E*). In male, the distal upper edge of the propodus is anteriorly produced into a protubrance with rounded apex which is furnished with a tuft of hairs (usually reaching to tip of the dactylus), the last joint is articulated below the protuberance of the propodus, somewhat elongated spoon-shaped, sometimes very thin, suddenly expanded outward immediately in front of the articulation, provided with a longitudinal excavation on upper surface for reception of the tuft of hairs (Fig. 13, *F*). This characteristic type is confined to *Penaeus* alone.

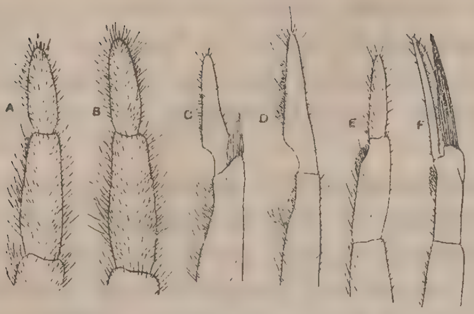

Fig. 13. Three types, Type I_1 (*A* and *B*), Type I_2 (*C* and *D*), and Type I_3 (*E* and *F*), of third maxilliped. *A*, *Metapenaeopsis lamellatus*, male (65mm in body-length) × 4.8; *B*, *M. lamellatus*, female (68.5mm), × 4.8; *C*. *Aristaeus virilis*, male (146mm), × 4,8; *D*, *A. virilis*, female (117.5mm), × 6; *E*, *Penaeus penicillatus*, female (126mm), × 2.8; *F*, *P. penicillatus*, male (121 mm), × 2.8.

b. Phylogenetical, morphological, and taxonomic considerations on mouth-parts.

Phylogenetical and morphological consideration. In regard to the mandibular palp, three types: Type–E_1–E_3, are recognized as given already. Among them Type–E_1 appears nearest to that of larval form of *Penenaus japonicus* (HUDINAGA, 1942), Type–E_2 intermediate in general aspect between Types, E_1 and E_3. Hence, the Type–E_1 may be taken most primitive of the three.

It should be noticed herewith, that the configuration of the mandibular palp of most species of Penaeidae exhibits a parallelism to the habit. The palp of the following Aristaeinae and Solenocerinae, namely, *Aristaeus virilis*, *Aristaeomorpha foliacea*, *Hymenopenaeus lucasii H. aequalis* and *Parahaliporus sibogae*, which are generally believed to be bathypelagic in habit, is of Type–E_1, slender and somewhat pediform as in that of other Aristaeinae, e.g., *Benthesicymus*, *Hepomadus*, *Gennadas*, and so forth. Thus the respiratory channels of these Penaeids are incompletely sheltered by the palp (Fig. 14, *D*–*F*). The appendage in qeestion of all the examined forms referable to genus, *Solenocera*, which probably inhabit sub-bathypelagic waters, belongs to Type–E_2. The second segment of the appendage is narrowed distally, triangular in outline, and broader than that of Type–E_1, whereas, the respiratory channels of *Solenocera* are rather completely sheltered by mandibular palp (Fig. 14, *C*). Finally, the palp of most species belonging to Penaeinae and Eusicyoninae, which live in littoral or sub-littoral waters, is of Type–E_3, and is sufficiently so broad as to cover completely the respiratory channels (Fig. 14, *A* and *B*). However, exception is found in some deep-sea forms of genera, *Metapenaeopis, Eusicyonia,* and *Penaeopsis*, e.g., *M. coniger, M. latus, E. inflexa, E. bitulans, P. rectactus*, etc., in which the palp undergoes no modification.

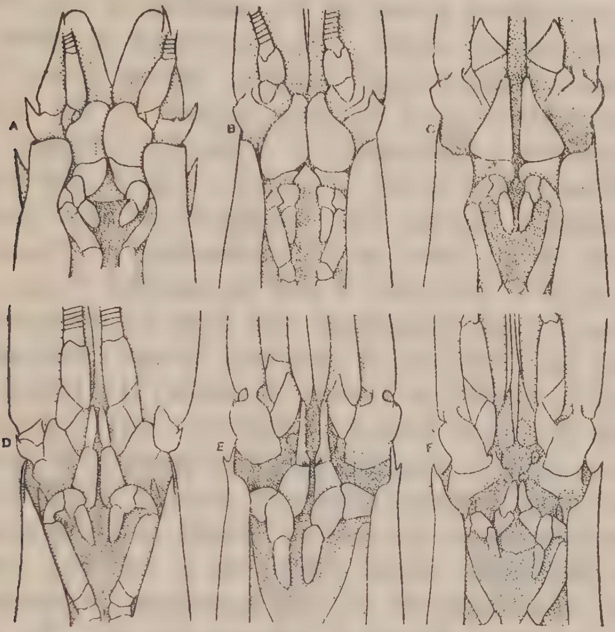

Fig. 14. Ventral aspect of oral region. *A, Eusicyonia lancifer japonica ; B, Penaeus japonicus ; C, Solenocera prominentis ; D, Parahaliporus sibogae ; E, Aristaeomorpha foliacea ; F, Aristaeus virilis.*

The maxillulary palp is again referable to three categories: Types, F_1–F_3, mostly based on the number of the segments, of which the palp is composed. As to the palp, BATE (1888, p. XXXV) mentions "sometimes it is two-jointed, never more". Moreover, BARKENROAD (1934, p. 6) states "the maxillulary palp in all Penaeinae which I have examined is composed of single segment." In reality, it is found, however, not segmented in Type–F_1, two-segmented in Type–F_2, and even three-segmented in Type–F_3. Remarkably enough, Type–F_2 is peculiar to *Penaeus*, and occurs in most (12 out of 14) species dealt with of this genus. Moreover, *Penaeus caramote*, a Mediterranean form, has been known to carry four segmented maxillulary palp (CALMAN, 1910, p. 266). But such case is not met with, so far as the present inspection goes. In metamorphosis of the palp in question of *Penaeus japonicus* (HUDINAGA, *op. cit.*), it is at first short, unsegmented and then becomes longer and segmented. Thus the types, F_2 and F_3 may be taken more specialized than Tpye-F_1.

Among all the components of maxilla, the anterior gnathobasic endite, the endopodite and the exopodite vary scardely in feature throughout all the species examined. But the posterior gnathobasic lacinia is liable to degenerate in shape of the proximal lobule. Three types, G_1–G_3, are defined basing on the condition of the proximal lobule of the basal gnathobasic endite. The maxilliped of genus, *Funchalia*, which has been regarded most primitive among living Penaeidae by previous investigators as it is very similar to the Jurassic form, *Antrimpos speciosus*, is ascribable to Type-G_3, according to Bouvier (1908) and Burkenroad (1936). However, Type-G_1 (the proximal lobule of basal gnathobasic lacinia well developed) is most generalized and simlar to the larval form of the appendage of *Penaeus japonicus* (Hudinaga, *op. cit*). Therefore it may be said that Type-G_1 is the most primitive, Type-G_3 most specialized, and Type-G_2 intermediate between Types, G_1 and G_3. This idea is supported by the following facts. The metamorphosis of maxilla of *Leander paucidens* (De Haan) and *Paratya compressa* (De Haan) as studied by Yokoya (1931) reveals that maxilla of *L. paucidens* entirely lacks the proximal gnathobasic lacinia in adult form as in all other Japanese species of *Leander* (Kubo, 1942). That of *P. compressa* is devoid of the posterior lobule of the proximal gnathobasic endite in adult form (Kubo, 1938) as is the case with Type-G_3. However, the transformation of the appendage in question of these Palaemonoid and Atyid shrimps is palingenetic, viz., the appendage of them is initially provided with four inner lobules as in Type-G_1, and subsequently assumes its adult form reducing the posterior one or two inner lobules.

The first maxilliped is referred into two types such as Type-H_1 and H_2. Type-H_1 is characterized by having unsegmented endopodite, and Type-H_2 by having segmented one. Type-H_1 is confined to *Eusicyonia*, and similar to the maxilliped of larval form of *Penaeus japonicus*, in which the endopodite of the appendage appears unsegmented in larvae smallor than 7.29 mm long but becomes segmented at least in ones larger than 10.37 mm long (Hudinaga, *op. cit.*). Thus it follows that Type-H_1 is taken as more primitive than the other.

Of the third maxilliped, three Types, I_1–I_3, have been recognized based on the feature of the last two segments. Type-I_1 is most generalized, Type-I_2 is peculiar to *Aristaeus virilis* only. Type-I_3 is common to all the species of *Penaeus*. Type-I_2 is intermediate between Type-I_1 and Type-I_3 in many respects. It is revealed that Type-I_3 is transformed from a condition which intimately resembles that of Type-I_1. The tuft of hairs lying on distal upper border of the propodus and the dorsal

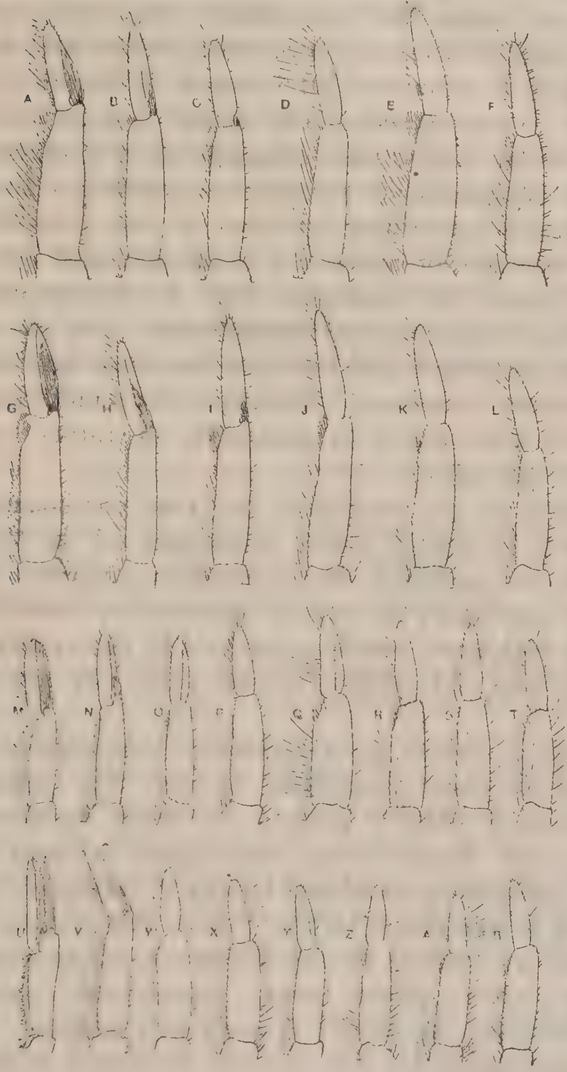

Fig. 15. Metamorphosis of distal two joints of third maxilliped of *penaeus japonicus* (*A*–*F*), *Penaeus latisulcatus* (*G*–*L*), *Penaeus monodon* (*M*–*T*) and *Penaeus bubulus* (*U*–*B′*). *A*–*D*, *G*–*J*, *M*–*P*, and *U*–*X*, male; *E* and *F*, *K* and *L*, *Q*–*T*, and *Y*–*B′*, female. *A*, 188mm in body-length, × ca. 3; *B*, 89, × 6; *C*. 81, × 6; *D*, 62, × ca. 8; *E*, 190, × ca. 3; *F*, 89, × 6; *G*, 113.5, × ca. 3; *H*, 94, × 6; *I*, 89, × 6; *J*, 65, × ca. 8; *K*, 121, × ca. 3.5; *L*, 78, × 6; *M*, 118, × ca. 2.5; *N*, 106.5, × ca. 3.5; *O*, 76, × ca. 5; *P*, 59.5, × ca. 7; *Q*, 174, × ca. 2.5; *R*, 120, × ca. 2; *S*, 58.5, × ca. 7; *T*, 65, × ca. 5.5; *U*, 156, × ca. 1.5; *V*, 101.5, × ca. 5; *W*, 70.5, × 6; *X*, 52.5, × ca. 8.5; *Y*, 200, × ca. 1.5; *Z*, 78.5, × ca. 5; *A′*, 48, × ca. 8.5; *B′*, 135, × ca. 3.

longitudinal depression of the dactylus, both of which are particular for Type-I_3, seem to make their appearance when the animal measures about 81 mm long in *Penaeus latisulcatus*, 88 mm long in *P. japonicus*, 106.5 mm long in *P. monodon*, 101.5 mm in *P. bubulus* (Fig. 15).

Taxonomic considerations. The molar process of the mandible effords no taxonomic importance, inasmuch as it is almost invariable in general feature throughout all the species examined. The incisor one of the same apparatus sometimes furnishes a clue available for specific distinction by presence or absence of a pointed tooth near anterior end of the cutting edge. The andibular palp is supergenerically variable. The subfamilies, Aristaeinae and Solenocerinae may be separated from the subfamilies, Penaeinae and Eusicyoninae based on the feature of this appendage as stated elsewhere. Moreover, the genus, *Solenocera*, is well defined from all other genera in possession of rather small triangular distal article of the palp.

With regard to the maxillula, the two gnathobasic laciniae are almost invariable in general aspect throughout all the forms dealt with, hence they are not useful for the systematic purpose. But the endopodite is more significant for generic demarkation than for specific one, since the palp undergoes mostly considerable supergeneric modification in the configuration and number of the joints, by which the palp is composed.

The maxilla is almost superspecifically invariable in feature of the endopodite and the distal gnathobasic lacinia. The endopodite is mostly rounded, sometimes bluntly pointed on distal border in Penaeinae, Solenocerinae, and Eusicyoninae, flagelliform at apex in Aristainae. However, the proximal gnathobasic lacinia is subject to rather variation in aspect as in Pontoniniinae (KUBO, 1940). The genera, *Parapenaeopsis* and *Eusicyonia* are marked by this character, the lacinia is of Type-G_2 in the former, Type-G_3 in the latter. Remarkably enough, feature of the lacinia sometimes specifically changes in *Penaeus*.

All the maxillipeds are less variable in general feature, and furnish no many important characters for the taxonomy of the Penaeids. The endopodite of the first maxilliped is available to distinguish the subfamily, Eusicyoninae, in which it is not segmented, from other three subfamilies, Penaeinae, Solenocerinae, and Aristaeinae, in which it is five-jointed. Moreover, the appendage serves for recognition of Aristaeinae from Penaeinae and Solenocerinae, since the appendage is thickened and the last joint much shorter than the penult in Aristaeinae, and slender and apical joint much longer than the penult in Penaeinae and Solenocerinae. In the second maxilliped, the exopodite is supergenerically variable in size as given already. Besides, the meropodite sometimes is subject to considerable interspecific variation in proportion. The third maxilliped is seven-jointed, basal five joints are less variable in general configuration, but distal two ones vary specifically mostly in *Penaeus*. Therefore this appendage is especially significant for the classification of the genus. Further, the feature of the last two joints is useful for separation of *Aristaeus virilis* from all other Penaeids dealt with. The size, proportion of each segment in length to dactylus, and the relative growth in relation to carapace-length are sometimes valuable for the specific distinction of Penaeidae.

In short, the following features of the mouth-parts are found to be especially significant for the taxonomy of Penaeidae:—mandibular palp; endopodite of maxillula; proximal gnathobasic lacinia of maxilla; endopodite of first maxilliped; exopodite and meropodite of second maxilliped; and distal two joints of third maxilliped.

G. EXOPODITE OF THORACIC APPENDAGES

The exopodite of the thoracic appendages varies mostly supergenerically throughout all the species examined. Four types may be recognized, basing on the mode of the arrangement, viz., Types, J_1–J_4 (Table 4).

Type–J_1: An exopodite, although sometimes rudimentary, is present on all the thoracic appendages. The majority of the species dealt with belongs to this type, viz., all the species of *Metapenaeopsis, Parapenaeopsis, Solenocera, Hymenopenaeus, Parahaliporus, Penaeopsis, Miyadiella, Trachypenaeus, Trachypenaeopsis, Atypopeneus*, and *Parapenaeus*, and all other species of *Penaeus* except *Penaeus bubulus*. It should be noticed that the exopodites are very vestigial in second maxilliped to the last pereiopod of *Parahaliporus sibogae*, in the third maxilliped to the fifth limb of *Hymenopenaeus aequalis*, and in all the pereiopods of all the Parapenaei.

Type–J_2: This type merely differs from the preceding type in lacking the exopoidite laid down on the last pereiopod, and represented by all forms belong to *Metapenaeus* and *Penaeus bubulus*.

Table 4. Types of arrangement of exopodites of thoracic appendages. A, first maxilliped; B, second maxilliped; C, third maxilliped; D–H, first to fifth pereiopods.

Types	A	B	C	D	E	F	G	H
J_1	1	1	1	1	1	1	1	1
J_2	1	1	1	1	1	1	1	—
J_3	1	1	1	—	—	—	—	—
J_4	1	—	—	—	—	—	—	—

Type-J_3: The exopodite is absent on all the maxillipeds, present on each of the pereiopods. This type is exemplified by the annexed Aristaeinae: *Aristaeus virilis* and *Aristaeomorpha foliacea.*

Type-J_4: Characterized by having an exopodite on the first maxilliped only, and confined to *Eusicyonia.*

Remarks: Inasmuch as the exopodite attached to the first maxilliped is invariably present and almost uniform in feature throughout all the Penaeids laid down before the writer, it is not significant for the taxonomy of the Penaeids. Absence of the exopodite on the second and third maxillipeds is peculiar to Eusicyoninae. Two Aristaeinae, *Aristaeus virilis* and *Aristaeomorpha foliacea*, are characterized by lacking exopodite on all the pereiopods, and all the species of *Metapenaeus* and *Penaeus bubulus* by lacking that of the last leg. The following key is based on such matters noted above.

- A_1 Exopodite present on third maxilliped
  - B_1 Exopodite appears on first pereipod
    - C_1 Exopodite present on the last periopod ....Type-J_1 (*Hymenopenaeus, Parahaliporus, Solenocera, Penaeopsis, Matapenaeopsis, Parapenaeus, Parapenaeopsis, Miyadiella, Atypopenaeus, Trachypenaeus, Trachypenaeopsis,* and *Penaeus* except *P. bubulus*).
    - C_2 Exopodite absent on the last pereiopod ....Type-J_2 (*Metapenaeus* and *Penaeus bubulus*).
  - B_2 Exopodite absent on first pereiopod ....Type-J_3 (*Aristaeus* and *Aristaeomorpha*).
- A_2 Exopodite lacking on third maxilliped ....Type-J_4 (*Eusicyonia*).

H. SPINES OF THORACIC APPENDAGES

The spines of the thoracic appendages have been used as important tant generic and specific characters in the classification of the present group of animals. So far as the present investigation goes, a spine occurs at least on a certain joint from basis to merus of the appendages ranging from the third maxilliped to the third pereiopod in all examined species but *Parahaliporus sibogae* and *Parapenaeopsis gracillima.* Three spines are present in the former on the merus of the first pereiopod, and in the latter the armatures are absent altogether. The spine is, when present, usually inserted singly on disto-ventral bordes of the aforementioned segments. But such on the meropodite offers exception to the statement given above: located singly at the middle in the first pereiopod of *Hymenopenaeus lucasii* and *Hymenopenaeus aequalis*, several set almost equidistantly along the ventral edge of the first leg of *Parahaliporus sibogae*, and one near the disto-ventral margin in first to third pereiopods of *Aristaeus virilis.* Sexual difference is found in the following two cases: *Metapenaeus joyneri* and *Parapenaeopsis cornutus.* In adult male of *M. joyneri*, the basial spine of the third pereiopod is extraordinarily elongated and bears a hook at apex. In female of *P. cornutus*, the basial spine of the third limb is absent. The arrangement of the spines varies mostly superspecifically, and rarely specifically. Concerning the mode of the arrangement, the annexed 13 types may be recognized: Type–K_1–K_{13}.

Type–K_1: A basial spine present on third maxilliped and anterior two pereiopods. An ischial one on first pereiopod (Table 5, *A*). This type is represented by all *Metapenaeopsis.*

Type–K_2: An ischial spine only exists on third maxilliped (Table, 5, *B*). This type is peculiar to *Aristaeomorpha foliacea.*

Type–K_3: Each basial, ischial, and meropoditic spine present on first pereiopod, basial one on second limb (Table, 5, *C*). *Hymenopenaeus aequalis* and *H. lucasii* belong to this type.

Type–K_4: A basial and ischial spines, and four or five meropoditic ones are present on first pereiopod (Table, 5, *D*). Represented by *Parahaliporus sibogae* only.

Type–K_5: Basial spine exists on the pereiopods from first to third. Ischial one on first and second pereiopods (Table 5, *E*). This type is exemplified by a species, *Miyadiella pedunculata.*

Type–K_6: This type is very near to Type–K_5, only difference is that the ischial spine of second pereiopod is absent (Table 5, *F*). The following five fpecies of *Metapenaeus* are referred to this category: *Metapenaeus monoceros*, *M. intermedius*, *M. brevicornis*, *M. spinulatus*, and *M. affinis.* It should be noticed that the ischial spine of the first pereiopod of *M. affinis* and *M. spinulatus* is minute.

Type–K_7: Basial spine present on first and second pereiopods, ischial one on first one (Table 5, *G*). All the penaeids of the following three genera: *Trachypenaeus*, *Solenocera Eusicyonia*, and *Penaeus* except *P. japonicus* and *P. latisulcatus*, belong to this type.

Type–K_8: basial and ischial spines present on first pereiopod only (Table 5, *H*). Represented by *Parapenaeus*, *Penaeopsis* and *Trachypenaeopsis.*

Type–K_9: Basial spine only exists on first three pereiopods (Table 5, *I*). This type includes five species: *Metapenaeus joyneri*, *M. lysianassa*, *M. tenuipes*, *Parapenaeopsis maxillipedo*, and *P. cornutus.*

Type–K_{10}: Basial spine alone is set on first and second pereiopods (Table 5, *J*). Exemplified by most *Parapenaeopsis* and two *Penaeus*: *Parapenaeopsis hungerfordi*, *P. hardwickii*, *P. cultrirostris*, *P. sculptilis*, *P. tenellus*, *Penaeus japonicus*, and *P. latisulcatus.*

Type–K_{11}: Basial spine present on second and third pereiopods, ischial one on first and second legs (Table 5, *K*). Represented by *Atypopenaeus compressipes* only.

Type–K_{12}: Meropoditic spine exist on pereiopods from first to third

(Table 5, *L*). *Aristaeus virilis* belongs to this type.

Type-K_{13}: Any basial, ischial and meropoditic spines absent on all thoracic appendages posterior to second maxilliped (Table 5, *M*). *Parapenaeopsis gracillima* is included in this type. The annexed key indicates the relationship between the groups given above. The groups are splitted into two sections. The first section is characterized by possession of basial or ischial spine on third maxilliped, and again is divided into two subdivisions; and the second by lacking such spine on third maxilliped and also discernible into four subdivisions owing to presence or absence of basial, ischial, and meropoditic spines of first pereiopod.

Key to the groups

- A_1 Third maxilliped with basial or ischial spine
  - B_1 Third maxilliped with basial spine; first pereiopod with basial and ischial spines; second leg has basial one ....Type-K_1 (*Metapenaeopsis*)
  - B_2 Third maxilliped with ischial spine; first and second pereiopods without basial and ischial spine ....Type-K_2 (*Aristaeomorpha foliacea*)
- A_2 Third maxilliped without spines
  - C_1 First pereiopod armed with basial, ischial, and meropoditic spines
    - D_1 First pereiopod has a spine on maropodite; second leg with basial spine ....Type-K_3 (*Hymenopenaeus lucasii* and *H. aequalis*)
    - D_2 First pereiopod carries 4 or 5 spines on meropodite; second leg without spine ....Type-K_4 (*Parahaliporus sibogae*)
  - C_2 First pereiopod armed with basial and ischial spines
    - E_1 Second pereiopod has basial and ischial spines ....Type-K_5 (*Miyadiella pedunculata*)
    - E_2 Second pereiopod carries basial spine only
      - F_1 Third pereiopod with basial spine ....Type-K_6 (*Metapenaeus monoceros*, *M. affinis* *M. intermedius*, *M. spinulatus*, *M. brericornis*)
      - F_2 Third pereiopod lacking basial spine ....Type K_7 (*Trachypenaeus*, *Solenocera*, *Penaeus* except *P. japonicus* and *P. latisulcatus*, and *Eusicyonia*)
    - E_3 Second pereiopod without spines ....Type-K_8 (*Parapenaeus*, *Penaeopsis*, and *Trachypenaeopsis*)
  - C_3 First pereiopod furnished with basial spine only
    - G_1 Third pereiopod has basial spine ....Type-K_9 (*Metapenaeus joyneri*, *M. lysianassa*, *M. tenuipes*, *Parapenaeopsis maxillipedo*, and *P. cornutus*)
    - G_2 Third pereiopod without basial spine ....Type-K_{10} (*Penaeus japonicus*, *P. latisulcatus*, *Parapenaeopsis hungerfordi*, *P. hardwickii*, *P. cultrirostris*, *P. sculptilis*, and *P. tenellus*)
  - C_4 First pereiopod lacks basial spine

H_1 First pereiopod with a spine on merus; second and third legs with basial spine ....Type-K_{11} (*Atypopenaeus compressipes*)

H_2 First three pereiopods armed with a spine on meropodite ....Type-K_{12} (*Aritaeus virilis*)

H_3 First three pereiopods has no spine ....Type-K_{13} (*Parapenaeopsis gracillima*)

Table 5. Types of arrangement of spines attached to thoracic appendages. 3rd max., third maxilliped.

Type-K_1

Items	Basis	Ischium	Merus
3rd max.	1	—	—
1st leg	1	1	—
2nd leg	1	—	—
3rd leg	—	—	—

Metapenaeopsis.

Type-K_2

Items	Basis	Ischium	Merus
3rd max.	—	1	—
1st leg	—	—	—
2nd leg	—	—	—
3rd leg	—	—	—

Aristaeomorpha.

Type-K_3

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	1	1	1*
2nd leg	1	—	—
3rd leg	—	—	—

* located at middle.

Hymenopenaeus.

Type-K_4

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	1	1	4-5
2nd leg	—	—	—
3rd leg	—	—	—

Parahaliporus.

Type-K_5

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	1	1	—
2nd leg	1	1	—
3rd leg	1	—	—

Miyadiella.

Type-K_6

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	1	1	—
2nd leg	1	—	—
3rd leg	1	—	—

Metapenaeus affinis, M. monoceros M. intermedius, M. brevicornis, and *M. spinulatus.*

Type-K_7

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	1	1	—
2nd leg	1	—	—
3rd leg	—	—	—

Trachypenaeus, Solenocera, and *Eusicyonia.*

Type-K_8

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	1	1	—
2nd leg	—	—	—
3rd leg	—	—	—

Parapenaeus, Penaeopsis, and *Trachypenaeopsis.*

Type-K_9

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	1	—	—
2nd leg	1	—	—
3rd leg	1	—	—

Metapenaeus joyneri, M. lysianassa, M. tenuipes, Parapenaeopsis cornutus (basial spine of third leg is absent in female), *P. maxillipedo.*

Type-K_{10}

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	1	—	—
2nd leg	1	—	—
3rd leg	—	—	—

Penaeus japonicus, P. latisulcatus, Parapenaeopsis hungerfordi, P. hardwickii, P. cultrirostris, P. sculptilis, and *P. tenellus.*

Type-K_{11}

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	—	1	—
2nd leg	1	1	—
3rd leg	1	—	—

Atypopenaeus.

Type-K_{12}

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	—	—	1
2nd leg	—	—	1
3rd leg	—	—	1

Aristaeus.

Type-K_{13}

Items	Basis	Ischium	Merus
3rd max.	—	—	—
1st leg	—	—	—
2nd leg	—	—	—
3rd leg	—	—	—

Parapenaeopsis gracillima.

I. BRANCHIAE

a. General discussion

Branchiae afford very important criteria for the classification of Decepod Crustacea. Yet unfortunately, misinterpretation or even failure of recognition of some branchiae has not been of rare occurrence because of their very minute size in some species of Penaeidae. The writer has, therefore, scrutinized branchiae of a considerably large number of specimens of the group in question with especial reference to their arrangement, and has obtained some remarkable results as given in the following paragraphs.

To begin with *Aristaeus*, the branchial arrangement (Table 6, *B*) tallies completely with that given by ALCOCK (1901, p. 29) for the same genus. But it differs from that given by WOOD-MASON (1891, p. 279) in having pleuro-branchia on the second thoracic somite, arthro-branchia on the first, and mastigo-branchiae on the anterior five thoracic somites.

As regards *Solenocera*, the two arthro-branchiae on the first thoracic somite have never been put on record by prior investigators. These branchiae are so minute as liable to be overlooked, but not vestigial at all. On the contrary they are well differentiated with many branched filaments (Fig. 16, *C*). Of the two arthrobranchiae on the first thoracic somite, the posterior one is more developed than the other, and thus the total number of arthrobranchiae amounts to 14, arranged in double series on all thoracic somites anterior to the eighth somite (Table 6, *C*).

It may be mentioned that the branchiae of my specimens referable to *Hymenopenaeus* and *Paraliporus* are arranged as followos:—a pleuro-branchia is present on each of posterior six thoracic segments;

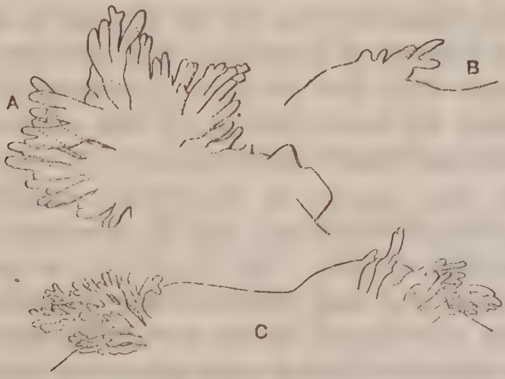

Fig. 16. Arthrobranchiae of first thoracic segment. *A*, *Trachypenaeus curvirostris*, ×60; *B*, *Parapenaeus lanceolatus*, ×24; *C*, *Solenocera prominentis*, ×24.

a rudimentary arthro-branchia exists on the first somite, and two full grown ones on each somite from second to seventh, a podobranchia on the second; and a mastigobranchia on each of the anterior seven somites (Table 6, *D*). This arrangement agrees altogether with that given by DE MAN (1911, p. 42) for *Haliporus sibogae* (=*Parahaliporus sibogae*), but is discrepant from BATE'S (1888, p. 284) branchial formula given for the genus, *Haliporus*, in having no podobranchiae on the third and fourth thoracic somites.

In *Parapenaeus*, the presence or absence of the rudimentary arthrobranchia of the first thoracic somite and the mastigobranchia of the third pereiopod has long been open to question. ALCOCK (*op. cit.*) states "the arthrobranch of the somite VII seems to be absent," BURKENROAD (1934, p. 107) says "rudimentary arthrobranch of VII without filaments," and BOUVIER (*op. cit.*, p. 108) indicates it in his branchial formula as "O (ou 2?)." The mastigobranchia in question was specified by DE MAN (1911, p. 78) as lacking in all the Indo-Pasific species of *Penaeus*, and by BURKENROAD (*op. cit.*, p. 108) in *P. americanus* and *P. longirostris* (—*P. paradoxus*). On the other hand, it was observed to exist by BOUVIER (*op. cit.*, p. 102) and PESTA (1918, p. 45) in *P. longirostris*. But, according to BALSS (1914, p. 10), it is sometimes present in *P. fissurus*. However, so far as my investigations go, the vestigial arthrobranchia is really present, attached to the first thoracic somite and provided with several filaments (Fig. 16, *B*), but the mastigobranchia is absent on the third pereiopod in the specimens referable to *Parapenaeus fissurus*, *P. lanceolatus*, *P. sextuberculatus*, and *P. investigatoris*.

It may be safely argued that the arthrobranchia of the first thoracic somite of *Trachypenaeus* was overlooked by ALCOCK (*op. cit.*, p. 43), inasmuch as it is rather vestigial. This branchia bears, it may be mentioned, dendroid filaments (Fig. 16, *A*) at least in my material.

The branchial formula of *Eusicyonia* was first given by BATE (*op. cit.*, p. 293). Since then this formula was accepted by many prior investigators without any correction except that rendered by A. MILNE-EDWARDS and BOUVIER (1909). BURKENROAD (1934 a, p. 117) examined the branchiae of four species of *Eusicyonia*, namely, *E. dorsaliris* (KINGSLEY), *E. stimpsoni* (BOUVIER), and *E. laevigata* (STIMPSON), and rectified the branchial formula. He found in his material a simply lamellar outgrowth arising from basal articular membrane of first maxilliped, but he did not take it as an arthrobranchia. This lamellar outgrowth is also present in seven other species of *Eusicyonia* of mine, and it is found lacking filaments as stated by BURKENROAD. However, it should be put as a varid one in the branchial formula for the genus, *Eusicyonia*, since it is apparently homologous with the branched arthrobranchiae found in almost all other Penaeidae.

b. Taxonomic consideration.

Arrangement of branchiae: So far as the present investigation goes, the number of the branchiae shows no individual variation, but demonstrates considerable superspecific (mostly intergeneric) modification. It ranges from 2 to 7 in pleurobranchiae, 11 to 14 in arthrobranchiae, 1 to 5 in podobranchiae, and 2 to 7 in mastigobranchiae. The pleurobranchiae are 2 in *Eusicyonia* alone, 4 in six genera, *Trachypenaeopsis*, *Trachypenaeus*, *Parapenaeopsis* and *Miyadiella;* 5 in five genera, *Atypopenaeus*, *Penaeopsis*, *Metapenaeus*, *Metapenaeopsis*, and *Parapenaeus;* 6 in four genera, *Pnaeus*, *Soleonocera*, *Hymenopenaeus*, and *Parahaliporus;* 7 in two genera, *Aristaeus*, and *Aristaeomorpha*. The arthrobranchiae are 11 in *Miyadiella;* 12 in ten genera, *Atypopenaeus*, *Penaeopsis*, *Parapenaeus*, *Penaeus*, *Trachypenaeus*, *Parapenaeopsis*, *Aristaeus*, and *Aristaeomorpha;* 13 in six genera. *Trachypenaeopsis*, *Hymenopenaeus*, *Parahaliporus*, *Metapenaeopsis*, *Metapenaeus*, and *Eusicyonia;* 14 in *Solenocera* alone. The podobranchia is 1 in fourteen genera, *Solenocera*, *Hymenopenaeus*, *Parahaliporus*, *Penaeus*, *Trachypenaeus*, *Trachypenaeopsis*, *Parapenaeopsis*, *Miyadiella*, *Atypopenaeus*, *Metapenaeus*, *Metapenaeopsis*, *Penaeopsis*, *Parapenaeus*, and *Eusicyonia;* 4 in *Aristaeus;* and 5 in *Aristaeomorpha*. The mastigobranchiae are 2 in two species *Parapenaeopsis tenella* and *P. hungerfordi;* 3 in *Trachypenaeus asper;* 4 in two genera, *Parapenaeus* and *Aristaeus;* 5 in eight genera, *Atypopenaeus*, *Metapenaeus*, *Metapenaeopsis*, *Penaeopsis*, *Trachypenaeopsis*, *Trachypenaeus*, *Miyadiella*, and *Eusicyonia;* 6 in two genera, *Penaeus* and *Aristaeus;* and 7 in four genera, *Aristaeomorpha*, *Solenocera*, *Parahaliporus*, and *Hymenopenaeus*. As given above, the number of arthrobranchiae and podobranchiae is less variable than that of pleurobranchiae and mastigobranchiae. Especially the number of podobranchia of all the species belonging to subfamilies, Penaeinae, Solenocerinae, and Eusicyoninae is single without exception. This character furnishes, therefore, nothing useful for discrimination of the Penaeids referable to the three subfamilies given above.

With reference to the number of the pleurobranchiae, the whole species dealt with are divisible into the following five supergeneric and superspecific assemblages, namely, Type-L_1-L_5.

Type-L_1: Seven pleuro-, twelve arthro-, four or five podo-, and six or seven mastigo-branchiae present. A pleurobranchia is supported on each thoracic segment posterior to the first somite, but the anterior six are vestigial. An arthro-branchia on either of the first and second thoracic somites, and two ones on each of the somites from third to seventh are present, of which that of the first somite is rudimentary. A podobranchia lies on each of the somite from second to fifth or sixth. A mastigobranchia is carried by each of the first seven or six somites. (Table 6, *A* and *B*).

This type is represented by *Aristaeomorpha foliacea* and *Aristaeus virilis*. The podobranchia of the sixth thoracic segment, and the mastigobranchia of the seventh segment is absent in *A. virilis*. The genera, *Hemipenaeus*, *Plesiopenaeus*, *Hepomadus*, and *Benthesicymus*, all of which belong to Aristaeinae, appear to be involved in this group according to ALCOCK (1901, pp. 29–43).

Type-L_2: Six pleuro-, 14–12 arthro-, one podo-, and seven or six mastigo-branchiae appear to exist. A pleurobranchia is present on each of the posterior six thoracic somites. One or two arthrobranchiae occur on the first and seventh somites, and a pair on each of the somites from second to sixth, those of the first somite are always vestigial. A podobranchia present on the second. A mastigo-branchia lies on each of the somite from first to seventh or sixth. (Table 6, *C–E*).

All the Penaeids of *Solenocera*, *Hymenopenaeus*, *Parahaliporus*, and *Penaeus*, pertain to the lump of this type. A rudimentary arthrobranchia is inserted on the first thoracic somite of *Parahaliporus*, *Hymenopenaeus*, and *Penaeus*; anterior one of the seventh of *Penaeus*; and mastigo-branchia of the seventh absent in *Penaeus*.

Type-L_3: five pleuro-, 12 or 13 arthro-, one podo-, and four or five mastigo-branchiae exist. A pleurobranchia is present on each thoracic somite from second to sixth or from third to seventh. A vestigial arthrobranchia lies on the first somite, a pair on each of the somites from the second to sixth, one or an anterior vestigial and posterior ones on the seventh. A podobranchia present on the second only. A mastigobranchia exists on each of all other anterior five thoracic somites except the third one, or each of all other anterior six thoracic somites (Table 6, *F–H*). *Atypopenaeus*, *Metapenaeopsis*, *Metapenaeus*, *Penaeopsis*, and *Parapenaeus* belong to this type.

It is peculiar to *Atypopenaeus* that the pleurobranchia of the second thoracic somite is present, and that of the seventh is absent. The anterior arthrobranchia of the seventh thoracic somite is simply bar-shaped, present in all species of *Metapenaeus* and all other *Metapenaeopsis* except *M. lamellatus*. The mastigo-branchia of the sixth thoracic somite is absent in *Parapenaeus*.

Type-L_4: Four pleuro-, 11–13 arthro-, one podo-, and 2–5 mastigobranchiae present. A pleurobranchia occur on each thoracic somite from third to sixth. A rudimentary arthrobranchia of the first somite is present or absent. Two ones always present on each of the segments from second to fifth, those of the sixth and seventh somites are one or two in number, and that of the last somite is present or absent. A podo-branchia lies on the second somite as in Types–L_2 and L_3. A mastigo-branchia invariably present on each of the anterior two somites, but that of each somite from third to fifth is present or absent (Table, 6, *I–N*).

This type is exemplified by *Trachypenaeopsis*, *Trachypenaeus*, *Parapenaeopsis*, and *Miyadiella*. The rudimentary arthro-branchia of the first thoracic somite, and one of those of the sixth are absent in *Miyadiella*. The anterior vestigial one of the seventh somite is characteristic to *Trachypenaeopsis*, and the branchia of the eighth somite to *Miyadiella*. The mastigobranchia of the sixth somite is lacking in *Parapenaeopsis*, and that of the fourth and fifth somites is absent in the following species: *Trachypenaeus asper*, *Parapenaeopsis tenellus*, and *P. hungerfordi*.

Type–L_5: Two pleuro-, 13 arthro-, one podo-, and five mastigo-branchiae are found to exist. A pleurobranchia is present on the second and third thoracic somites. An arthrobranchia on the first two somites, and a pair on the somites from third to seventh. A podo-branchia lies on the second somite. A mastigo-branchia exists on each of the first, second, and fourth to sixth somites (Table 6, *O*).

Table 6. Branchial arrangement. Seg., thoracic segments, r., rudimentary.

A. Type-L_1, *Aristaeomorpha.*

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	r	r	r	r	r	r	1	7
Arthrobranchiae	r	1	2	2	2	2	2	—	12
Podobranchiae	—	1	1	1	1	1	—	—	5
Mastigobranchiae	1	1	1	1	1	1	1	—	7
Total	2	4	5	5	5	5	4	1	31

B. Type-L_2, *Aristaeus.*

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	r	r	r	r	r	r	1	7
Arthrobranchiae	r	1	2	2	2	2	2	—	12
Podobranchiae	—	1	1	1	1	—	—	—	4
Mastigobranchiae	1	1	1	1	1	1	—	—	6
Total	2	4	5	5	5	4	3	1	29

C. Type-L_2, *Solenocera.*

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	1	1	6
Arthrobranchiae	2r	2	2	2	2	2	2	—	14
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	1	1	1	1	1	—	7
Total	3	4	4	4	4	4	4	1	28

D. Type-L_2, *Hymenopenaeus* and *Parahaliporus.*

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	1	1	6
Arthrobranchiae	r	2	2	2	2	2	2	—	13
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	1	1	1	1	1	—	7
Total	2	4	4	4	4	4	4	1	27

E. Type-L_2, *Penaeus.*

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	1	1	6
Arthobranchiae	r	2	2	2	2	2	1	—	12
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	1	1	1	1	—	—	6
Total	2	4	4	4	4	4	2	1	25

F. Type L_3, *Atypopenaeus* and *Penaeopsis.*

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	1	1	1	1	1	—	—	5
Arthrobranchiae	r	2	2	2	2	2	1	—	12
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	1	1	1	—	—	5
Total	1	5	3	4	4	4	1	0	23

G. Type-*L*₃, *Metapenaeus*, and *Metapenaeopsis*.

Gills \ Seg.	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	1	—	5
Arthrobranchiae	r	2	2	2	2	2	r+1	—	13
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	1	1	1	—	—	5
Total	2	4	3	4	4	4	2	0	23

H. Type-*L*₃, *Parapenaeus*.

Gills \ Seg.	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	1	—	5
Arthrobranchiae	r	2	2	2	2	2	1	—	12
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	1	1	—	—	—	4
Total	2	4	3	4	4	3	2	0	22

I. Type-*L*₄, *Trachypenaeopsis*.

Gills \ Seg.	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	—	—	4
Arthrobranchiae	r	2	2	2	2	2	r+1	—	13
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	1	1	1	—	—	5
Total	2	4	3	4	4	4	2	0	23

J. Type-*L*₄, *Trachypenaeus curvirostris*.

Gills \ Seg.	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	—	—	4
Arthrobranchiae	r	2	2	2	2	2	1	—	12
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	1	1	1	—	—	5
Total	2	4	3	4	4	4	1	0	22

K. Type-L_4, *Parapenaeopsis* (*P. cornutus, P. hardwickii, P. sculptiris, P. cultirostris*, and *P. gracillima*).

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	—	—	4
Arthrobranchiae	r	2	2	2	2	2	1	—	12
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	1	1	—	—	—	4
Total	2	4	3	4	4	3	1	0	21

L. Type-L_4, *Trachypenaeus asper.*

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	—	—	4
Arthrobranchiae	r	2	2	2	2	2	1	—	12
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	—	—	1	—	—	3
Total	2	4	3	3	3	4	1	0	20

M. Type-L_4, *Parapenaeopsis* (*P. tenellus P. hungerfordi*).

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	—	—	4
Arthrobranchiae	r	2	2	2	2	2	1	—	12
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	—	—	—	—	—	2
Total	2	4	3	3	3	3	1	0	19

N. Type-L_4, *Miyadiella.*

Seg. Gills	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	—	1	1	1	1	—	—	4
Arthrobranchiae	—	2	2	2	2	1	1	1	11
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	1	1	1	—	—	5
Total	1	4	3	4	4	3	1	1	21

O. Type-L_5, *Eusicyonia*; * only a lamella without filaments.

Gills \ Seg.	I	II	III	IV	V	VI	VII	VIII	Total
Pleurobranchiae	—	1	1	—	—	—	—	—	2
Arthrobranchiae	r*	1	2	2	2	2	r+1	—	12
Podobranchiae	—	1	—	—	—	—	—	—	1
Mastigobranchiae	1	1	—	1	1	1	—	—	5
Total	2	4	3	3	3	3	2	0	20

Represented by *Eusicyonia* only.

The arthrobranchia of the first thoracic somite is vestigial, lamellar, without any filaments. The anterior one of the seventh somite is simply bar-shaped like that of *Metapenaeus*, *Metapenaeopsis*, and *Trachypenaeus*.

The key given below is not only intended to reveal more detailed relation between the genera treated herein, but also to serve for the distinction of the supergeneric, generic, and superspecific groups.

A1 Pleurobranchiae are seven in number (anterior six vestigal), lying in single number on each thoracic somite from second to eighth ....Type-L_1.
  B1 Podobranchia present on sixth thoracic somite, mastigobranchia on the seventh somite ....*Aristaeomorpha*,
  B2 Podobranchia absent on sixth thoracic somite, mastigobranchia lacking on the seventh somite ....*Aristaeus*.
A2 Pleurobranchiae six in number, are present on each of posterior six thoracic somites ....Type-L_2.
  C1 Arthro-branchiae of seventh thoracic somite are two in number, mastigobranchia exist on the seventh somite.
    D1 Arthrobranchiae of first thoracic somite are vestigial, two in number ....*Solenocera*.
    D2 Arthrobranchia of first thoracic somite is vestigial, single in number ....*Hymenopenaeus*, *Parahaliporus*.
  C2 An arthrobranchia present on seventh thoracic somite; mastigobranchia absent on the seventh somite ....*Penaeus*.
A3 Pleurobranchiae are five in number ....Type-L_3.
  E1 Pleurobranchia absent on seventh thoracic somite ....*Atypopenaeus*.
  E2 Pleurobranchia present on seventh thoracic somite
    F1 Arthrobranchia of seventh thoracic somite are two in number, anterior one of which is minute bar-shaped ....*Metapenaeus* and *Metapenaeopsis* except *M. lamellatus*.
    F2 Arthobranchia of seventh thoracic somite well-developed, single in number
      G1 Mastigobranchia of sixth thoracic somite present ....*Penaeopsis*, and *Metapenaeopsis lamellatus*.
      G2 Mastigobranchia of sixth thoracic somite lacking ....*Parapenaeus*.
A4 Pleurobranchiae are four in number, lying on each thoracic somite from third to sixth ....Type-L_4.

H_1 .Arthrobranchia absent on the last thoracic somite
  I_1 Arthro-branchiae of seventh thoracic somite found in a pair, anterior one of which is minute with bar-shaped appearance ....*Trachypenaeopsis.*
  I_2 Arthrobranchia of seventh thoracic somite single in number
    J_1 Mastigobranchia present on sixth thoracic somite
      K_1 Mastigobranchia of fourth and fifth thoracic somites found to exist ....*Trachypenaeus curvirostris.*
      K_2 Mastigobranchia of fourth and fifth thoracic somites absent ....*Trachypenaeus asper.*
    J_2 Mastigobranchia absent on sixth thoracic somite
      L_1 Mastigobranchia of fourth and fifth thoracic somites exists ....*Parapenaeopsis* except *P. tenellus*, and *P. hungerfordi.*
      L_2 Mastigobranchia of fourth and fifth thoracic somites missing ....*Parapenaeopsis tenellus*, and *P. hungerfordi.*
H_2 Arthrobranchia present on the last thoracic segment ....*Miyadiella.*
A_5 Pleurobranchiae are two in number, occur on second and third thoracic somites; a vestigial bar-shaped and a well-developed arthrobranchia present on seventh thoracic somite ....*Eusicyonia.*

Furthermore the arrangement of the four kinds of branchiae lying on each thoracic segment from first to eighth is also considerably variable. As to the arrangement, the following 14 types: *Ba–Bn*, may be recognized (Table 7). Type–*Ba* is characterized by absence of branchia. Type–*Bb* with a mastigobranchia. Type–*Bc* with an arthrobranchia. Type–*Bd* with an arthrobranchia and a mastigobranchia. Type–*Be* with a pair of arthrobranchiae. Type–*Bf* with two arthrobranchiae and a mastigobranchia. Type–*Bg* with two arthrobranchia, a podobranchia, and a mastigobranchia. Type–*Bh* with a pleurobranchia.

Table 7. *Pl.* pleurobranchiae; *Ar.* arthrobranchiae; *Po*, podobranchiae, *Ma.*, mastigobranchiae.

Types	Pl.	Ar.	Po.	Ma.
Ba	0	0	0	0
Bb	0	0	0	1
Bc	0	1	0	0
Bd	0	1	0	1
Be	0	2	0	0
Bf	0	2	0	1
Bg	0	2	1	1
Bh	1	0	0	0
Bi	1	1	0	0
Bj	1	1	0	1
Bk	1	1	1	1
Bl	1	2	0	0
Bm	1	2	0	1
Bn	1	2	1	1

Type–*Bi* with a pleurobranchia and an arthrobranchia. Type–*Bj* with a pleurobranchia, and arthrobranchia, and a mastigobranchia. Type–*Bk* with a pleurobranchia, an arthrobranchia, a podobranchia and a mastigobranchia. Type–*Bl* with a pleurobranchia and a pair of arthrobranchiae. Type–*Bm* with a pleurobranchia, two arthrobranchiae, and a mastigobranchia. Finally Type–*Bn* with a pleurobranchia, two arthrobranchiae, a podobranchia, and a mastigobranchia.

As shown in Table 8, the branchial arrangement is assortable to three types, Type–*Bb*, *Bd* and *Bf*, mostly Type–*Bd* in the first thoracic segment; to two types, *Bk* and *Bm*, mostly the latter type, in the second segment; to three types, *Bl–Bn*, mostly Type–*Bl*, in the third segment; to four types, *Bf* and *Bl–Bn*, mostly Type–*Bm* in fourth and fifth segments; to five types, *Bf*, *Bj*, and *Bl–Bn*, mostly Type–*Bm* in the sixth segment; also to five types, *Bc*, *Be*, *Bi*, *Bl*, and *Bm*, mostly Type–*Bc* and *Bm*, in the seventh somite; and to three types, *Ba*, *Bc* and *Bh*, mostly Type–*Ba* in the last thoracic somite. Accordingly, *Solenocera* is marked from all others examined by the branchial arrangement of the first thoracic segment, *Miyadiella* by that of the first, sixth and eighth segments, *Penaeus* by that of the third, *Eusicyonia* by that of the segments from fourth to sixth, and *Aristaeus* by that of the last thoracic segment.

Feature of branchiae; the branchiae of Penaeidae are invariable in feature within a species except individual variation. But the branchiae become, as a whole, smaller in size anteriorly. The pleurobranchiae and podobranchiae are dendroid without exception. The arthrobranchiae are usually dendroid. However, those of the first thoracic somite are so vestigial that it is sometimes difficult to recognize the existence of the organ and frequently simply lamellar. The anterior arthrobranchia of the seventh thoracic somite is much degenerated assuming minute bar-shape in *Metapenaeus*, *Metapenaeopsis* (except *M. lamellatus*), *Trachypenaeopsis*, and *Eusicyonia*, and entirely absent in the rest. The mastigobranchiae attached to the first and second maxillipeds are always leaf-shaped and exhibit neither interspecific nor intergeneric variation, whilst those of the third maxilliped and all the pereiopods are usually Y-shaped, bearing well developed stalk and two distal laminar lobules. One of the distal lobules sometimes undergoes superspecific modification in shape partly or entirely missing.

The facts given above may be summarized as follows:—the feature of pleurobranchiae, arthrobranchiae except the anterior arthrobranchiae of the seventh thoracic somite, podobranchiae, and mastigobranchiae of the anterior two thoracic somite afford nothing available for the classification of the animals. On the other hand, the feature of the anterior arthrobranchia of the seventh thoracic segment and the mastigobranchiae

Table 8.

	Types	Genera and Species
First thoracic somite	Bb	*Miyadiella.*
	Bd	*Aristaeus, Aristaeomorpha, Hymenopenaeus, Parahaliporus, Penaeus, Penaeopsis, Metapenaeus, Trachypenaeopsis, Atypopenaeus, Parapenaeopsis, Trachypenaeus, Parapenaeus, Eusicyonia.*
	Bf	*Solenocera.*
Second thoracic somite	Bk	*Aristaeus, Aristaeomorpha, Eusicyonia.*
	Bm	*Parahaliporus, Hymenopenaeus, Solenocera, Miyadiella, Penaeus, Penaeopsis, Metapenaeus, Trachypenaeopsis, Atypopenaeus, Parapenaeopsis, Trachypenaeus, Parapenaeus, Metapenaeopsis.*
Third thoracic somite	Bl	*Parahaliporus, Hymenopenaeus, Solenocera, Miyadiella, Penaeopsis, Metapenaeus, Trachypenaeopsis, Atypopenaeus, Parapenaeopsis, Trachypenaeus, Parapenaeus, Metapenaeopsis Eusicyonia.*
	Bm	*Penaeus.*
	Bn	*Aristaeus, Aristaeomorpha.*
Fourth and Fifth thoracic somites	Bf	*Eusicyonia.*
	Bl	*Parapenaeopsis tenellus, P. hungerfordi, Trachypenaeus asper.*
	Bm	*Solenocera, Hymenopenaeus, Penaeus, Metapenaeus, Metapenaeopsis, Penaeopsis, Parapenaeus, Atypopenaeus, Trachypenaeopsis, Miyadiella, Parapenaeopsis cornutus, P. hardwickii, P. sculptiris, P. cultrirostris,* and *Trachypenaeus curvirostris.*
	Bn	*Aristaeus* and *Aristaeomorpha.*
Sixth thoracic somites	Bf	*Eusicyonia.*
	Bj	*Miyadiella.*
	Bl	*Parapenaeus* and *Parapenaeopsis.*
		Aristaeomorpha, Solenocera, Hymenopenaeus, Penaeus, Trachypenaeus, Trachypenaeopsis, Atypopenaeus, Penaeopsis, Metapenaeus, and *Metapenaeopsis.*
	Bn	*Aristaeus.*
Seventh thoracic somite	Bc	*Trachypenaeus, Miyadiella, Atypopenaeus,* and *Parapenaeopsis.*
	Be	*Trachypenaeopsis, Metapenaeopsis,* and *Eusicyonia.*
	Bi	*Penaeus, Penaeopsis,* and *Parapenaeus.*
	Bl	*Aristaeus.*
	Bm	*Aristaeomorpha, Hymenopenaeus, Solenocera,* and *Parahaliporus.*
Eighth thoracic somite	Ba	*Penaeopsis, Metapenaeus, Trachypenaeus, Atypopenaeus, Trachypenaeopsis, Parapenaeus, Parapenaeopsis, Metapenaeopsis,* and *Eusicyonia.*
	Bc	*Miyadiella.*
	Bh	*Aristaeomorpha, Aristaeus, Hymenopenaeus, Solenocera,* and *Penaeus.*

lying on the thoracic somites posterior to second maxilliped sometimes serve for generic criterion but rarely a specific one.

J. PETASMA

a. Structure of petasma

Petasma of Penaeids is made up of right and left petasmal endopodites which are in adult form, usually firmly united together with each other by a numerous cincinnuli supported along each inner margin. As exhibited diagramatically in Fig. 17, each of the petasmal endopodite is composed of median or inner (*ML*) and lateral or outer (*L L*) lobes. Each lobe is again inwardly folded and forms two subdivisions: dorsal or anterior (*d l*) and ventral or posterior (*v l*) lobules respectively.

The ventral lobule of the lateral lobe is furnished with three longitudinal ridges: ridges, *a*, *b*, and *c*, on outer side. The ridge-*a* is located near the boundary between the dorsal and ventral lobules. The ridge–*b* is set near the median line of the outer surface of the ventral lobule. The ridge–*c*, which is usually much smaller than other two, is laid on the outer surface near the ventral rim of the lobule.

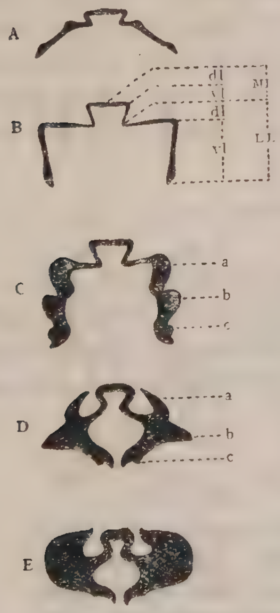

Fig. 17. Diagramatic representation of five types of petasmal cross-section. *A*, Type-PC_1; *B*, Type-PC_2; *C*, Type-PC_3; *D*, Type-PC_{4a}; *E*, Type-PC_5; *a*, ridge-*a*; *b*, ridge-*b*; *c*, ridge-*c*; *dl* dorsol lobule; *LL*, lateral lobe; *Ml*, median lobe; *vl*, ventral lobule.

Processes-*a* and *b*, and spines–*a–e*, are peculiar to the petasms of *Solenocera* and *Parapenaeus*, respectively. The process–*a* is situated near anterior end of ventral free margin of lateral lobe, usually spatulate, abruptly recurves outward at apex which is furnished with many pointed setae. The process-*b* stands on outer surface near middle of dorsal lobule of lateral lobe, pointed or rounded at apex, and sometimes armed with acute setae (Fig. 27, *a* and *b*). The spine-*a* is placed on disto-lateral edge of the ventral lobule of the lateral lobe, the spine-*b* on distal fringe of dorsal lobule of lateral lobe, the spine–*c* on distolateral rim of the dorsal lobule of the median lobe, the spine–*d* on outer surface near inferior margin of the ventral lobule of the lateral lobe, and the spine–*e* on dorso-lateral edge near posterior end of the dorsal lobule of the median lobe (Fig. 28, *a–e*).

The asymmetrical petasma, which is characteristic to *Metapenaeopsis* only, was described for the first time in detail by KISHINOUYE (1929, pp. 280–283), and subsequently by BURKENROAD (1934, pp. 20–23), by whom the nomenclature given by KISHINOUYE has been emended to be capable of more general application. However, a careful morphological investigation of the petasma reveals that BURKENROAD'S terminology for the appendages of the distal piece is somewhat in confusion in indicating their location, and thus his scheme should be again revised as follows:—

	Present author	BURKENROAD	KISHINOUYE
(a)	Right distoventral projection	Distomedian lobe	Proximal part
(b)	Right distodorsal lobule	Distoventral projection	External piece
(c)	Distomedian lobule	Distolateral lobe	Second distal part
(d)	Distoventral flap	Distoventral flap	Convoluted distal part
(e)	Left distoventral projection	Left external piece	Left external piece
(f)	Left distodorsal lobule	Left internal piece	Left internal piece
(g)	Inner intermediate strip	” ” ”	” ” ”
(h)	Outer intermediate strip	” ” ”	” ” ”
(i)	Left dorsal piece	” ” ”	” ” ”

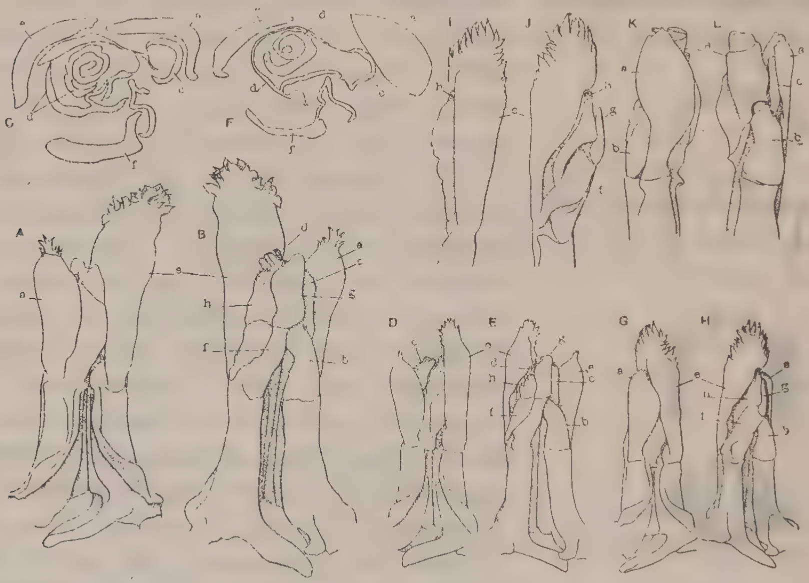

Fig. 18. Petasma of *Metapenaeopsis acclivis*, 53.5 mm in body-length, (*A–C*). *Metapenaeopsis, barbatus*. 64 mm in body-length, (*D–F*), and *Metapenaeopsis durus*, 77 mm in body-length, (G–*L*), *A*, ventral aspect, ×4.8; *B*, dorsal aspect, ×4.8; *C*, cross-section at about middle of inner intermediate strip, ×16; *D*, ventral aspect, ×2.8; *E*, dorsal aspect, ×2.8; *F*, cross-section at about middle of inner intermediate strip, ×16; *G*, ventral aspect, ×2.8; *H*, dorsal aspect, ×2.8; *I*, ventral view of distal portion of left petasmal endopodite, ×4.8; *J*, dorsal view of the same portion as in *I*, ×4.8; *K*, ventral aspect of distal portion of right petasmal endopodite, ×4.8; *L*, dorsal aspect of the same portion as in *K*, ×4.8; *a*, right disto-ventral projection; *b*, right disto-dorsal lobule; *c*, disto-median lobule; *d*, disto-ventral flap; *e*, left disto-ventral projection; *f*, left disto-dorsal lobule; *g*, inner intermediate strip; *h*, outer intermediate strip.

Both the petasmal endopodites are transversely divided into nearly equal proximal and distal pieces. The distal piece of the right petasmal endopodite consists of four elements, viz., right distoventral projection (*a*), right disto-dorsal lobule (*b*), disto-ventral flap (*c*) and disto-median lobule (*d*) (Fig. 18, *a-d*). The right distoventral proection is laid down on disto-ventral margin of the proximal portion. The right disto-dorsal lobule arises from the distodorsal edge of tne proximal portion. The disto-ventral flap is produced from the ventro-median edge of the proximal portion, but partly covered by the disto-ventral projection and disto-dorsal lobule. The disto-median lobule is inserted on the basal lateral edge of the disto-ventral flap, and hidden beneath the right disto-ventral projection. The distal portion of the left petasmal endopodite is again made up of four parts, viz., left disto-ventral projection (*e*), left disto-dorsal lobule (*f*), inner intermediate strip (*g*), and outer intermediate strip (*h*) (Fig. 18, *e–h*). The disto-ventral projection is situated on disto-ventral edge of the proximal portion. The disto-dorsal lobule is set on the disto-dorsal edge of the proximal portion. The inner and outer intermediate strips are small appendages placed on distal inner and distal outer margins of the disto-dorsal lobule. But sometimes the three pieces. *i. e.*, disto-dorsal lobule, inner and outer intermediate strips, are found united and form a rather slender structure to which I propose to call left dorsal piece (*i*).

b. Cross-section of petasma

The cross-section of petasma, of which little attention has been paid by prior investigators, is significant for detailed interpretation of the organ. The section is prepared through about the middle of the apparatus of adult form. As regards the general feature of the section, a considerable variation is found to exist. Tentatively, however, the following five supergeneric types may be recognized (Fig. 17), namely, Types-PC_1-PC_5, into which all of the Penaeids dealt with are ascribable.

Type-PC_1: In this probably most primitive type, which includes *Aristaeus virilis*, *Aristaeomorpha foliacea*, *Miyadiella pedunculata*, and *Penaeopsis rectactus*, median lobes are comparatively thick, as thick as lateral lobes; inner margins are free in even adult form of *A. virilis*, *A. foliacea*, and *M. pedunculata*, but knit together with each other in *P. rectactus*. The angle between dorsal and ventral lobules of lateral

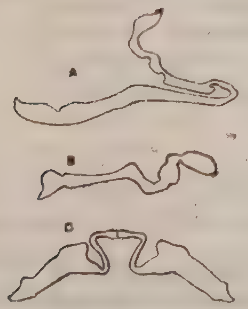

Fig. 19. Type-PC_1 of cross-section of petasma. *A*, *Aristaeus virilis*, ×6.8; *B*, *Aristaeomorpha foliacea*, ×8.4; *C*, *Penaeopsis rectactus*.

lobe is obtuse, more than 160°. Main channel, if present, is very shallow. Ridges–*a*–*c* are less developed (Figs., 17, *A* and 19).

Type–PC_2: This type embraces *Penaeus*, *Solenocera* and *Hymenopenaeus*. Median lobe and dorsal lobule of lateral lobe are thin, comparatively broad. Dorsal lobule of lateral lobe narrower than the other in *Penaeus* and *Hymenopenaeus*, and broader than the other in *Solenocera*. Dorsal and ventral lobules of lateral lobe inserted almost at right angles. Main channel deep, sub-rectangular in cross-section. Ridges–*a*–*c* less developed (Figs. 17, *B* and 20).

Type–PC_3: Represented by *Parapenaeus* and *Trachypenaeus*. Median lobe thicker than that of Type–PC_2. Ventral lobule of lateral lobe much thicker and broader than the other. Dorsal and ventral lobules of lateral lobe make an angle nearly 90°, and main channel deep and subrectangular in cross-section as is the case with Type–PC_2. Ridges–*a*–*c* are rather rounded at apex (Figs. 17, *C* and 21).

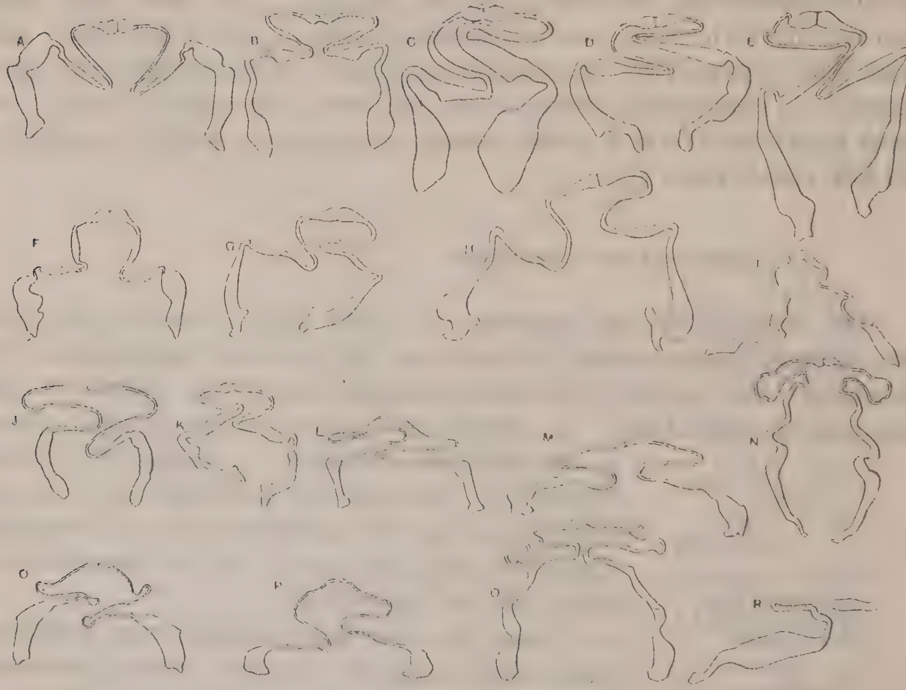

Fig. 20. Type-PC_2 of cross-section of petama. *A*, ***Penaeus monodon***; *B*, *Penaeus latisulcatus*; *C*, *Penaeus japonicus*; *D*, *Penaeus bubulus*; *E*, *Penaeus esculentus*; *F*, *Penaeus teraoi*; *G*, *Penaeus merguiensis*; *H*, *Penaeus indicus*; *I*, *Penaeus penicillatus*; *J*, *Penaeus stylirostris*; *K*, *Penaeus brevirostris*; *L*, *Solenocera depressa*; *M*, *Solenocera prominentis*; *N*, *Solenocera brevipes*; *O*, *Solenocera subnuda*; *P*. *Solenocera faxoni*; *Q*, *Hymenopenaeus lucasii*; *R*, *Hymenopeaeus aequalis*. *A*, *F*, *L*, *M*, and *O*-*R*, ×8.2; *B* and *G*, ×16; *C*, *E*, *H*, *I* and *N*, ×12; *D* and *K*, ×6; *J*, ×4.8.

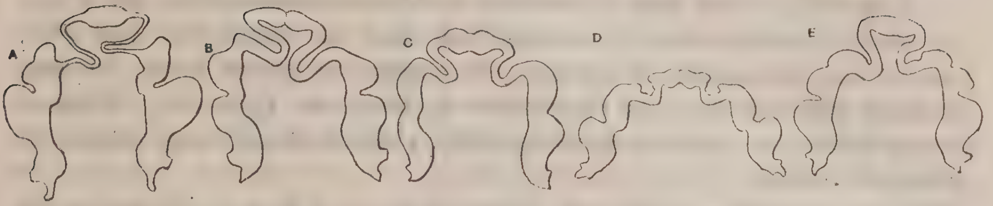

Fig. 21. Type-PC_3 of cross-section of petasma. *A*, *Trachypenaeus curvirostris*; *B*, *Parapenaeus sextuberculatus*; *C*, *Parapenaeus lanceolatus*; *D*, *Parapenaeus investigatoris*; *E*, *Parapenaeus fissurus*. *A*, ×12; *B*, *D*, and *E*, ×16; *C*, ×28.

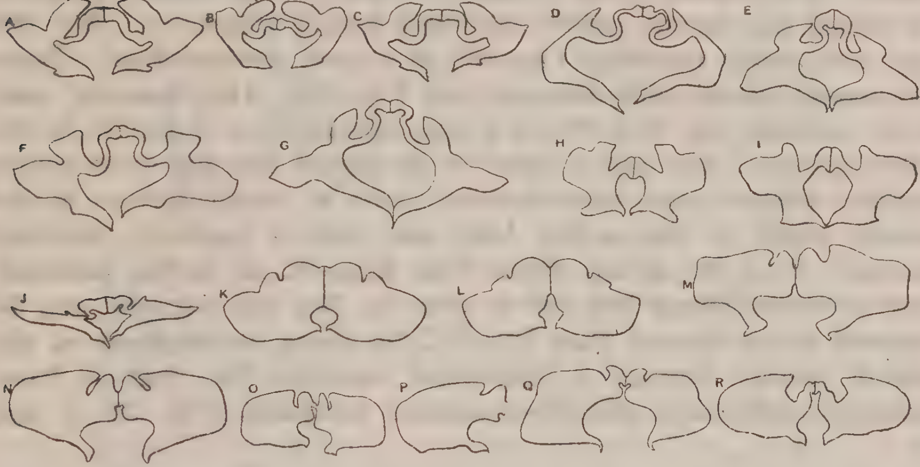

Fig. 22. Types, PC_{4a}, PC_{4b}, and PC_5 of cross-section of Petasma. *A*, *Metapenaeus monoceros*; *B*, *Metapenaeus tenuipes*; *C*, *Metapenaeus affinis*; *D*, *Metapenaeus joyneri*; *E*, *Eusicyonia cristata*; *F*, *Eusicyonia curvirostris*; *G*, *Eusicyonia lancifer japonica*; *H*, *Parapenaeopsis hungerfordi*; *I*, *Parapenaeopsis cornutus*; *J*, *Parapenaeopsis tenellus*; *K*, *Parapenaeopsis cultrirostris*; *L*, *Parapenaeopsis hardwickii*; *M*, *Metapenaeopsis barbatus*; *N*, *Metapenaeopsis acclivis*; *O*, *Metapenaeopsis durus*; *P*, *Metapenaeopsis coniger*; *Q*, *Metapenaeopsis dalei*; *R*, *Metapenaeopsis lamellatus*. *A*, *B*, and *D*, ×6; *C*, *O*, and *R*, ×8.4; *E* and *F*, ×20; *G*, *H*, *J–N*, and *P*, ×16; *I* and *Q*, ×12.

Type–PC_4: *Metapenaeus*, *Parapenaeopsis*, and *Eusicyonia* are included in this type. Median lobe as thick as that of Type–PC_3. Lateral lobe is much thicker than median lobe. Ventral lobules of lateral so strongly turn medially that the ventral free lips are much juxtaposed or even come into contact with each other. Ridges–*a*–and *b* are usually strikingly developed with sharp apex, ridge–*c* usually minute. Ridge–*a* directed sidewise. Ridge–*b* is as large as or somewhat smaller than ridge–*a* in most cases of *Metapenaeus* and *Eusicyonia*, much smaller than ridge–*a* in *Parapenaeus* (Figs. 17, *D* and 22, *A–L*).

Type-PC_5: This type is peculiar to *Metapenaeopsis* (Figs. 17, *E* and 22, *M–R*). Median lobe is as thick as that of Types-PC_3 and PC_4. Lateral lobe enormously thickened. Free edges of lateral lobes are not so much laid near-by from each other as those of Type-PC_4. Ridge-*a* is well-developed, directed dorso-medially, ridge-*b* absent, and ridge-*c* is minute if present.

Phylogenetical remarks. Type-PC_1 is simplest in feature, found in younger form of many different species, besides *Aristaeus virilis*, *Aristaeomorpha foliacea*, *Miyadiella pedunculata*, and *Penaeopsis rectactus.* Type-PC_2 is distinguished from Type-PC_1 in having deep channel, and intermediate between types-PC_1 and PC_3 in general aspect. In Type-PC_3, the specialization is mostly exhibited in the ventral lobule of the lateral lobe bearing rather developed lateral ridges-*a–c*. But this type very closely resembles Type-PC_2 in general configuration. Type-PC_4 appears considerably different from Type-PC_3. One, however, may safely conclude that Type-PC_4 is a type modified from Type-PC_3 by the following way: The ventral lobule of the lateral lobe first turns ventro-medially, ridge-*a* grows dorso-medially as far as dorsal surface of the dorasal lobule of the median lobe, and ridge-*b* markedly stretches outward. Type-PC_5 greatly differs from Type-PC_4 in having outstandingly thickened lateral lobe and no ridge-*b*. But this type also may be regarded as transformed from Type-PC_4 by strong development of the ridge-*b* passing through a transitional condition like that of *Parapenaeopsis cultrirostris* and *Parapenaeopsis hardwickii* (Fig. 22, *K* and *L*).

So far as the present item is concerned, there is a monophyletic relationship through Type-PC_1 to Type-PC_5. Thus the petasma commonly known open petasma is more primitive than asymmetrical (so-called) petasma. The condition of petasma with such well developed ridges is a specialized feature.

c. General feature of petasma

At least in the taxonomic studies of Penaeidae, much attention was paid to the petasma by many prior investigators since BATE (1888), and the feature of the organ has been used as an important systematic criterion, mostly for the distinction of species. A scrutiny, however, has led the writer to find that the organ varies from simpler condition to more intricate one in the species dealt with, and this character is not only valuable as a specific trait but also indispensable for the consideration of the interrelationship between the species, genera, and even subfamilies of the present family.

It may be mentioned that the present author's comparative analysis of the general configuration of petasma enabled him to recognize the annexed eleven distinct types, viz., Types, M_1–M_{11}.

Type–M_1: this type which is represented by *Miyadiella* only, simply lamellar (Fig. 23, *G* and *H*). Cross-section is of Type–PC_1. Right and left petasmal endopodites are isolated from each other. Each endopodite subrectangular in outline, provided with two similar strips with rounded apex on distal border, not folded longitudinally, devoid of cincinnuli along inner margin. Median and lateral lobes as well as dorsal and ventral lobules are not differentiated whatever.

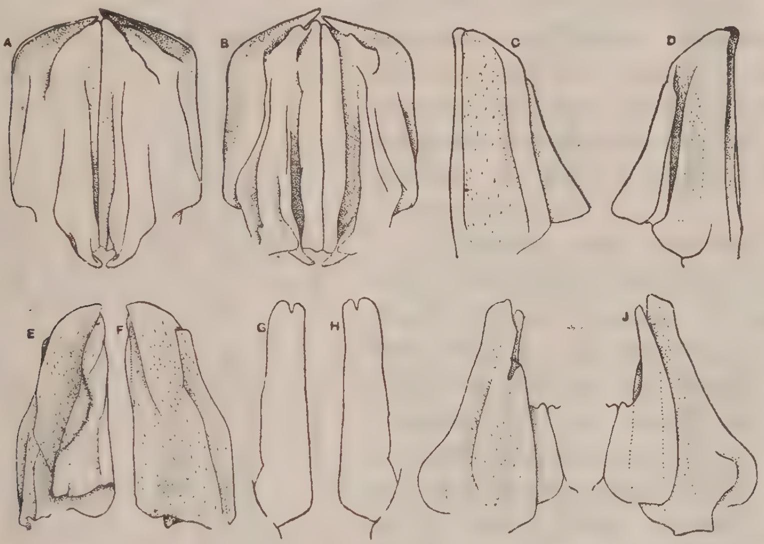

Fig. 23. Petasma of Type-M_1 (*G* and *H*) and Type-M_1 (*A*-*F*, *I* and *J*). *A*, *D*, *F*, *G*, and *J*, dorsal aspect; *B*, *C*, *E*, *H*, and *I*, ventral aspect. *A* and *B*, *Penaeopsis rectactus* (92 mm in body-length), ×6; *C* and *D*, *Aristaeomorpha foliacea* (127 mm), ×4.8; *E* and *F*, *Aristaeus virilis* (148 mm), ×2.8; *G* and *H*, *Miyadiella pedunculata* (20 mm), ×40; *I* and *J*, *Parahaliporus sibogae* (115 mm), ×4.8.

Type–M_2: exemplified by the following species: *Aristaeus virilis*, *Aristaeomorpha foliacea*, *Penaeopsis rectactus* and *Parahaliporus sibogae*. The petasma is rather simple, of type–PC_1 in cross-section, covered with rather sparsely set short hairs (Fig. 23, *A*–*D*, *E*, *F*, *I*, and *J*). Both right and left petasmal endopodites united with each other in *Penaeopsis rectactus* and *Parahaliporus sibegae*, not united in *Aristaeus virilis* and in *Aristaeomorpha foliacea*, and folded longitudinally. Proximal border of each endopodite has a papilla-like protuberance directed posteromedially in *Penaeopsis rectactus*, no appendages in other species. Distolateral margin provided with a horn or strip directed forward or anteromedially in all other species except *Aristaeomorpha foliacea*.

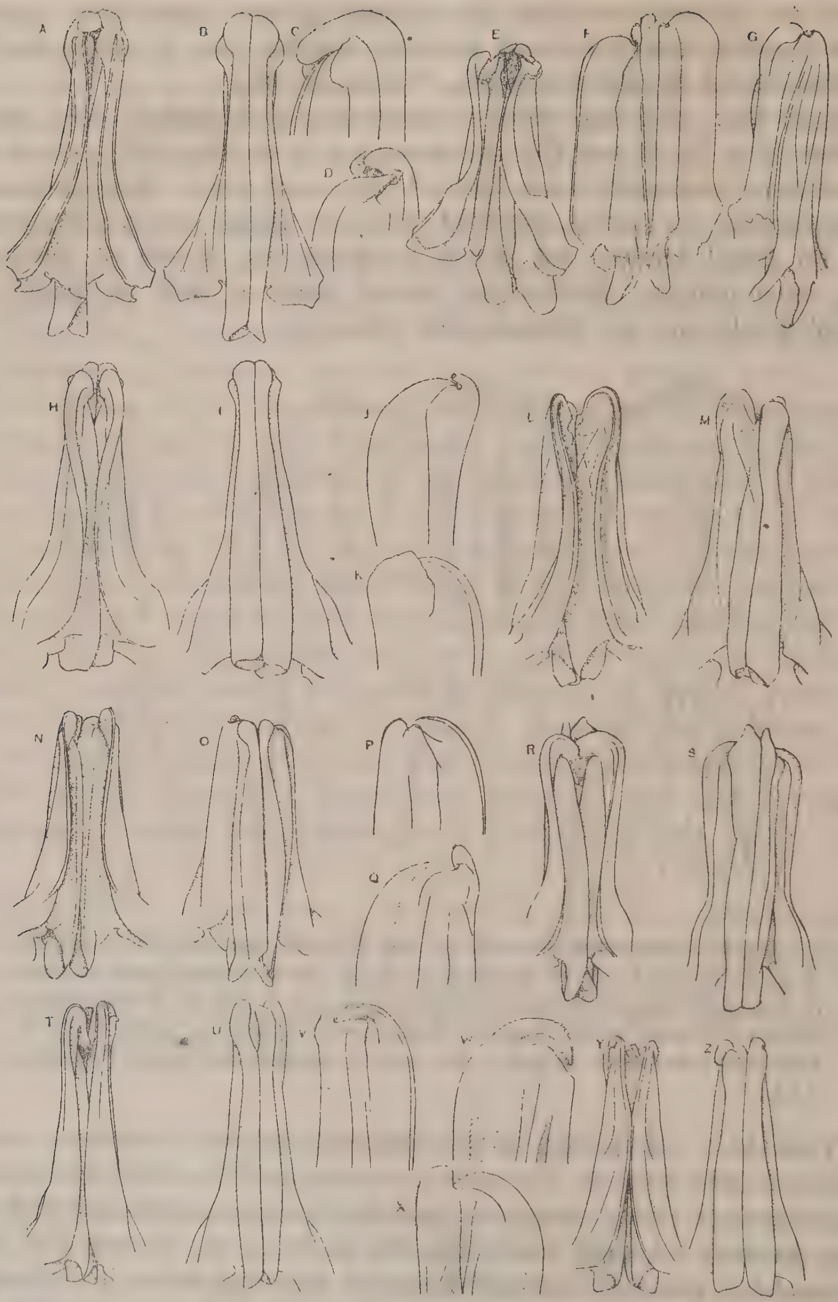

Fig. 24. Ventral (*A, E, F, H, L, N, R, T,* and *Y*), dorsal (*B, G, I, M, O, S, U,* and *Z*), and lateral (distal portion) (*C, D, J, K, P, Q, V, W,* and *X*) aspect of petasma referable to Type-M_3. *A C, Penaeus japonicus,* 128 mm in body-length (37 mm in carapace-length); *D* and *E, Penaeus latisulcatus,* 145 (41); *F* and *G, Penaeus longistylus,* 147.7 (40.4); *H J Penaeus monodon,* 144 (32); *K M, Penaeus bubulus,* 190 (54); *N P, Penaeus teraoi,* 135 (39); *Q S, Penaeus orientalis,* 146 (41.5); *T-V, Penaeus penicillatus,* 121 (31); *W Z, Penaeus indicus,* 120 (28.5). *A, B, F, G, H, I,* and *K,* ×4.8; *C, D, J, W* and *X,* ×8.4; *E, L, M,* and *Q S,* ×2.8; *F, G, Y,* and *Z,* ×5.6; *N* and *O,* ×6; *T* and *U,* ×6.4.

Type–M_3: the petasma of this type which is represented by all other forms referable to the genus *Penaeus* except *P. stylirostris* and *P. vannamei*, is pod-like, considerably compressed laterally, with deep channel, is of type–PC_2 in cross-section. Median lobe rather thin, somewhat membranous, prolonged posteriorly forming a subcylindrical tube, usually distally differentiated into a free small thickened protuberance which is variable in size, sometimes bent over the distral margin of lateral lobe. Lateral lobe broader and thicker than median one: ventral margin considerably thickened, well calcified, acutely pointed at apex, abruptly recurved upward in subterminal portion which is serrated with a number of minute but stout spines (Figs. 24 and 25).

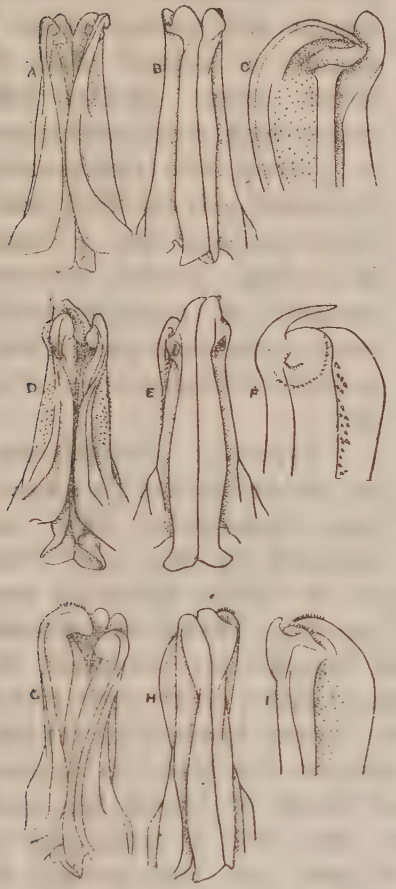

Fig. 25. Ventral (*A*, *D*, and *G*), dorsal (*B*, *E*, and *H*), and lateral (distal portion) (*C*, *F*, and *I*) aspects of petasma referable to Type–M_3. *A–C*, *Penaeus merguiensis*, 34 mm in body-length (19.8 mm in carapace-length); *D-F*, *Penaeus brevirostris*, 128 (34); *G-I*, *Penaeus esculentus*, 129 (33.2). *A* and *B*, ×6; *C*, ×16. *D-F*, ×2.8; *C-I*, ×4.8.

Type–M_4: the apparatus of this type represented by two American Pacific forms, *Penaeus stylirostris P. vannamei*, is very similar to that of Type–M_3 in general feature. But valuable clues, by which the present type are distinguishable from Type–M_3, are as follows:—each ventral margin of the lateral lobes is thin and soft, rounded or bluntly pointed at apex (Fig. 26).

Type–M_5: This type is represented by all the species which belong to genera. *Hymenopenaeus* and *Solenocera*. The organ is somewhat laterally compressed, with rather deep channel, Type–PC_2 in cross-section, furnished with the process–*a* and process–*b* (which is sometimes absent). Median lobe broad, membranous. Lateral lobe rather thick, well calcified. Distal margin of both the median and lateral lobes fringed with many pointed setae. Proximal one of median lobe truncate (Fig. 27).

Type–M_6: In this type, which

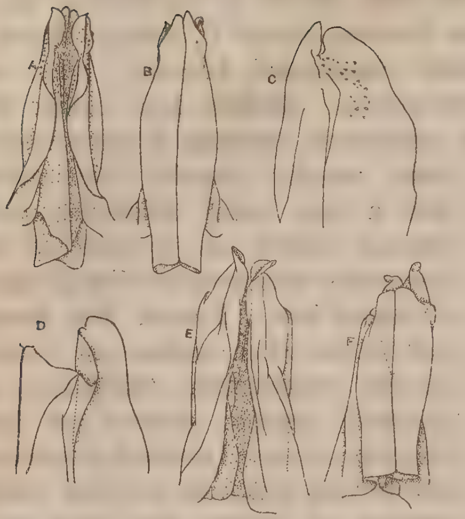

Fig. 26. Ventral (*A* and E), dorsal (*B*, *D*, and *F*), and lateral (distal portion) (*C*) aspects of petasma referable to Type-M_4. *A–C*, *Penaeus stylirostris*, 147 mm in body-length (41 mm in carapace-length); *D–F*, *Penaeus vannamei*, 138 (35.5). *A* and *B*, ×2.8; *C* and *D*, ×4.8; *E* and *F*, ×3.2.

involves *Parapenaeus*, the apparatus rather laterally compressed, with deep channel is of Type–PC_3 in cross-section, ends in a pair of fleshy ragged petaloid appendages which are greatly intricated with many lobules and overlap about a quarter of ventral edges of lateral lobes. Median lobe rather thick, armed with spine–*e*. Lateral lobe considerably thickened, well calcified, posteriorly produced into a large, ill-calcified process directed medially or posteromedially, much wider than median lobe, provided with spines–*a–d* (Fig. 28).

Type–M_7; *Parapenaeopsis hardwickii* and *Parapenaeopsis cultrirostris* only are included in this type. The petasma is strongly depressed, subrectangular in outline, somewhat narrowed distally. Cross-section belongs to Type–PC_4. Median lobe extends well beyond distal margin of lateral lobe, considerably thickened, ill-calcified and rounded on distal edge, produced into a short horn which is directed sidewise on disto-lateral border. Dorsal lobule of lateral lobe furnished with a rather large triangular process with blunt tip directed outward near proximal margin. Ventral lobule of lateral lobe well calcified, provided a little nearer to inner edge than to outer one of ventral surface with a low ridge, which in most part runs parallel to inner margin of the lobule in question, but abruptly curves inwards near its both anterior and posterior ends, furnished with a rather small round-topped protuberance on posterior margin near inner edge; carries a large depressed auriculate projection with rounded outer border directed sidewise on basal lateral fringe; and has a well calcified disto-lateral horn which is pointed at tip, directed sidewise, a little longer than that of median lobe. Median borders of lateral lobes are straight in most part but suddenly curve outward and again become straight running a trifle antero-laterally in distal one-fifth, rounded at disto-median angle, so that there exists somewhat T-shaped gap between distal borders of median lobes and those of ventral lobules of lateral lobes (Fig. 29).

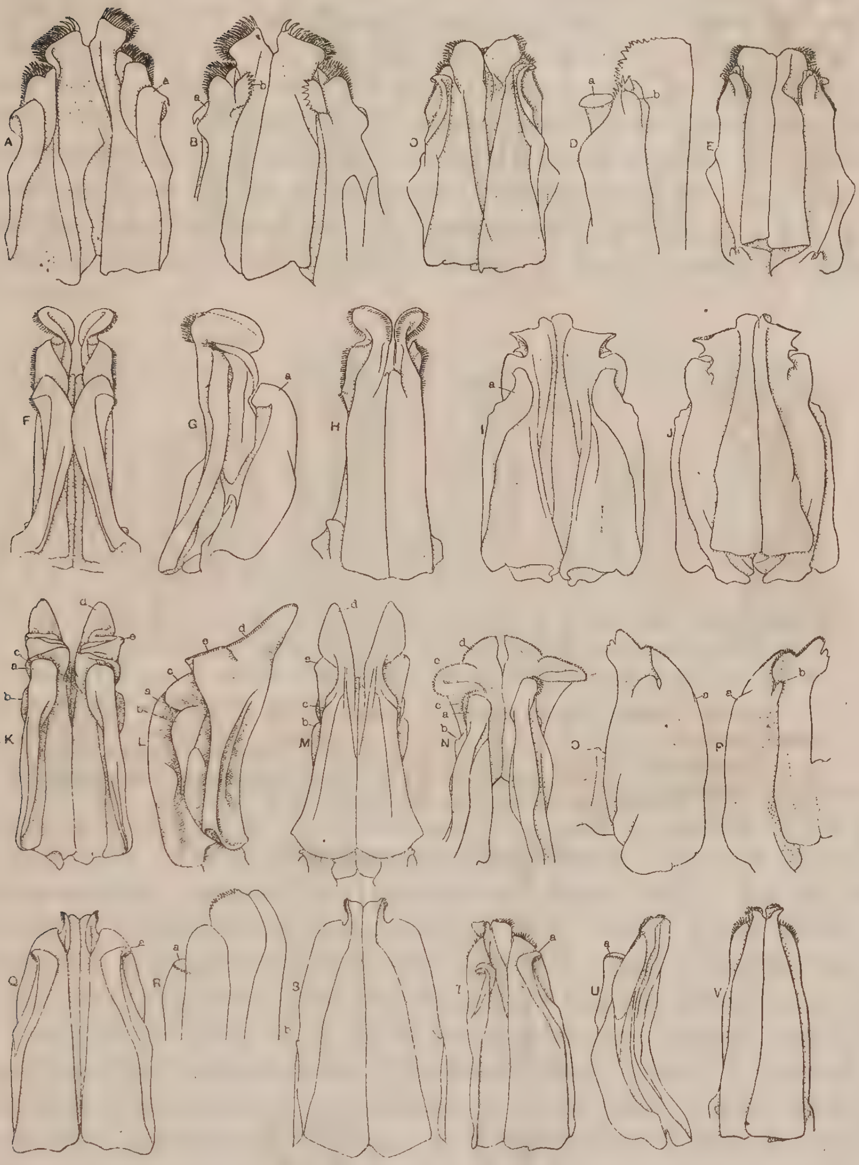
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Fig. 27. Ventral (*A, C, F, I, K, N, O, Q,* and *T*), dorsal (*B, E, H, J, M, P, S,* and *V*), and lateral (*D, G, L, R,* and *U*) aspects of petasma belonging to Type-M_5. *A* and *B*, *Solenocera pectinulata,* ca. 38 mm in body-length (10 mm in carapace-length); *C–E*, *Solenocera faxoni,* 50 (14.8); *F–H*, *Solenocera brevipes,* 46 (13); *I* and *J*, *Solenocera subnuda,* 61.5 (18.2); *K–M*, *Hymenopenaeus lucassi,* 103 (19.5); *N*, *H, lucassi,* 39 (9.5); *O* and *P*, *Hymenopenaeus aequalis,* (14.6); *Q–S*, *Solenocera prominentis,* 65 (18); *T–V*, *Solenocera depressa,* 58 (17). *A, B, D, N* and *R*, ×8.4; *C, E, I–M, Q,* and *S V*, ×4.8; *F–H, O* and *P*, ×6.

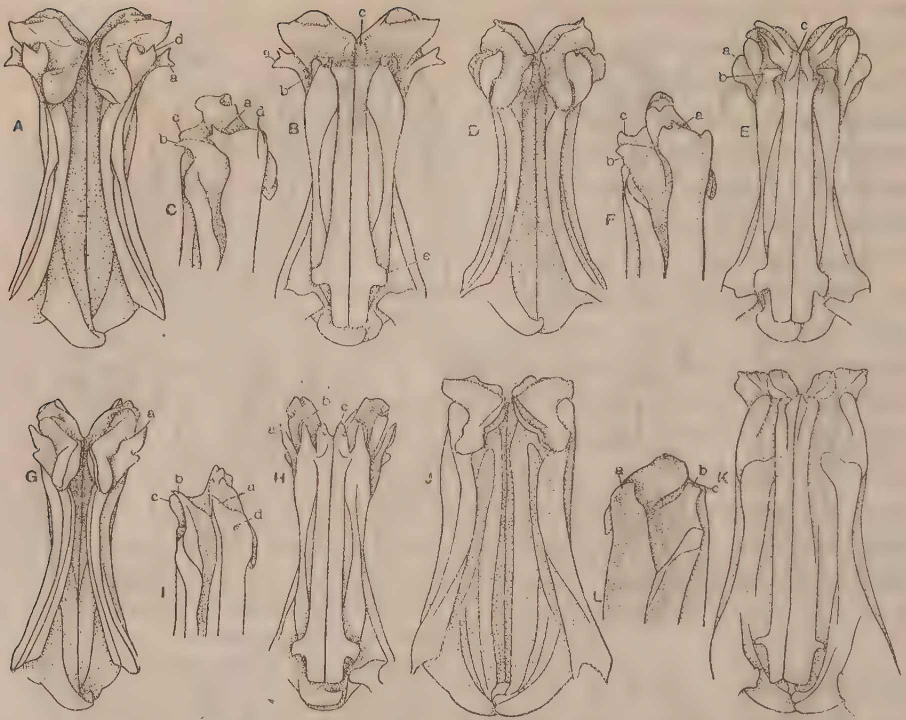

Fig. 28. Ventral (*A*, *D*, *G*, and *J*), dorsal (*B*. *E*, *H*, and *K*), and lateral (distal portion) (*C*, *F*, *I*, and *L*) aspects of petasma referable to Type-M_6. *A*-*C*, *Parapenaeus fissurus*, 74 mm in body-length (19 mm in carapace-lengtn); *D F*, *Parapenaeus sextuberculatus*, 85 (21.5); *G*-*I*, *Parapenaeus lanceolatus*, 85 (21.5); *J*-*L*, *Parapenaeus investigatris*, 63 (14.6). *A*-*I*, ×6; *J*-*L*, ×10.

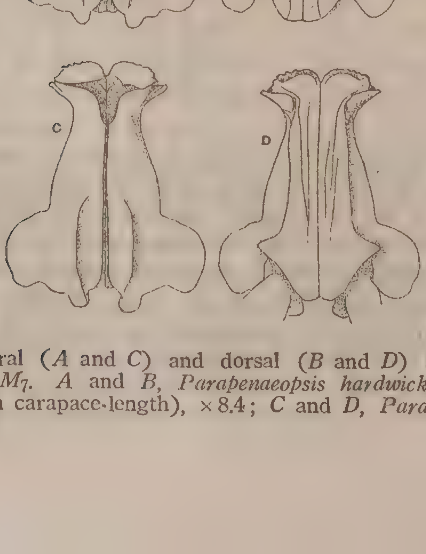

Fig. 29. Ventral (*A* and *C*) and dorsal (*B* and *D*) aspects of petasma referable to Type-M_7. *A* and *B*, *Parapenaeopsis hardwickii*, 58 mm in body-length (15.5 mm in carapace-length), ×8.4; *C* and *D*, *Parapenaeopsis cultrirostris*, 65 (17), ×6.

Type-M_8: Type-M_8 is peculiar to *Eusicyonia*. Petasma is depressed as in that of Type-M_7: subrectangular in outline, about twice as long as wide, is of Type-PC_4 in cross-section. Dorsal lobule of lateral lobe with a pair of short stout spines directed anteriorly on distal border. Ventral lobule of lateral lobe is provided with one or two short pointed spines directed laterally or antero-laterally at disto-lateral angle, a notch on distal border at middle or somewhat nearer to disto-median angle than to disto-lateral one, and sometimes a large pointed projection on lateral edge near anterior end. Ridge-*c* is explicit about in proximal half (Fig. 30).

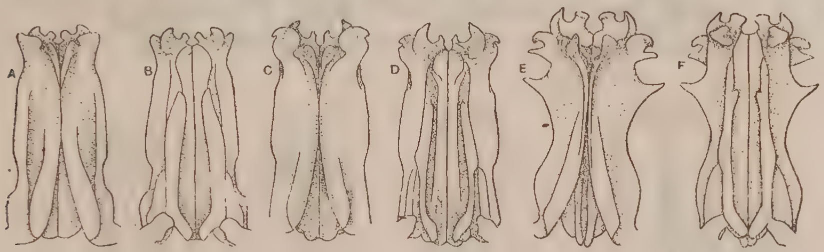

Fig. 30. Ventral (*A*, *C*, and *E*), and dorsal (*B*, *D*, and *F*) aspects of petasma referable to Type-M_8. *A* and *B*, *Eusicyonia cristata*, 43 mm in body-length (12 mm in carapace-length); *C* and *D*, *Eusicyonia lancifer japonica*, 47 (15); *E–F*, *Eusicyonia curvirostris*, 57.4 (14.3). *A*, *B*, *E* and *F*, ×6.4; *C* and *D*, ×6.

Type-M_9: petasma of this type, which is represented by *Metapenaeus*, is considerably depressed, subrectangular in outline, about two and half times as long (except appendages) as wide, and is of Type-PC_4 in cross-section. Median lobe ill-calcified, rather thick. Lateral lobe well calcified, much thicker than median lobe. Each dorsal lobule of median lobe bears either a plate like projection which is slender, pointed at apex, concavo-convex with convex surface upward, directed forward and recurved dorsally, or a hood-like projection, produced anteriorly. Lateral lobe has a conspicuous disto-lateral horn which is pointed or truncate at apex, directed antero-laterally or laterally. Dorsal lobule of lateral lobe produced posteriorly to a projection which is distally expanded with rounded apex directed inward on posterior edge near inner angle. Ventral lobule of lateral lobe has its posterior edge gently curved sidewise. Ridges, *a–c*, are well developed. Ridge-*a* is markedly dilated at about middle. Ridge-*c* is very low, defined well in almost proximal half, lies almost parallel to median border of ventral lobule of lateral lobe (Fig. 31).

Type-M_{10}: In this type which is represented by *Parapenaeopsis tenellus*, *P. cornutus*, *P. hungerfordi*, *Atypopenaeus compressipes*, *Trachypenaeus curvirostris*, and *T. asper*, the petasma depressed in *P.*

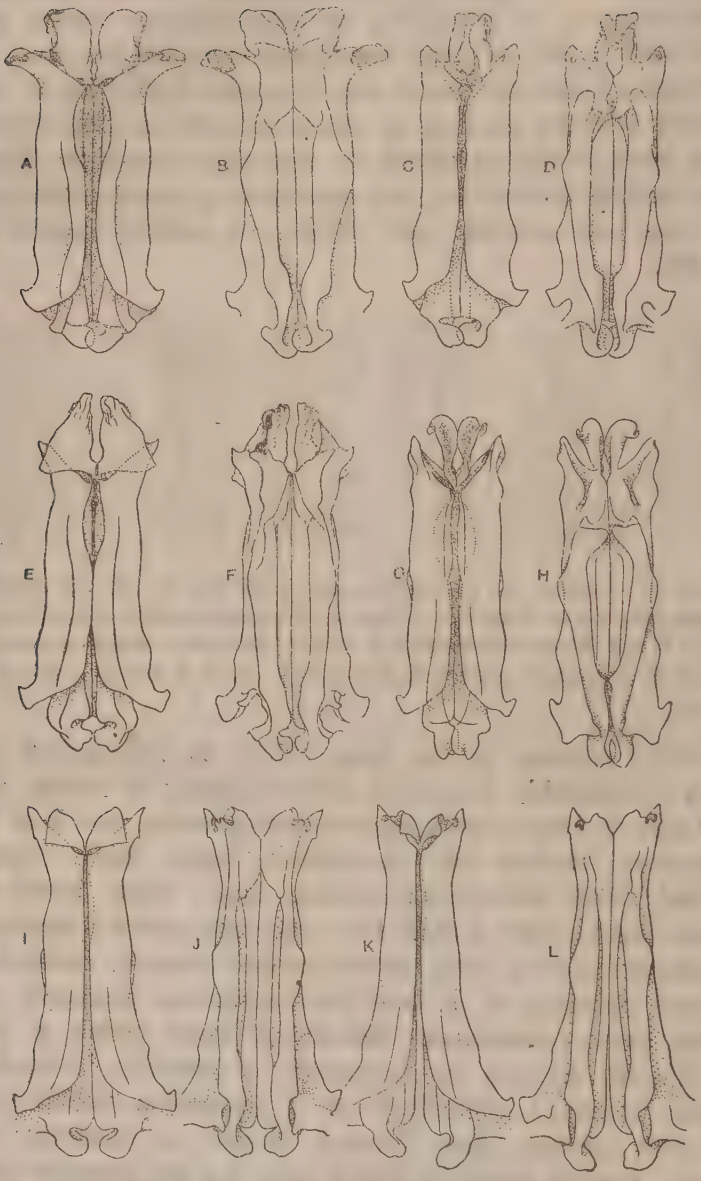

Fig. 31. Ventral (*A*, *C*, *E*, *G*, *I*, and *K*), and dorsal (*B*, *D*, *F*, *H*, *J*, and *L*) aspects of petasma referable to Type-M_9. *A* and *B*, *Metapenaeus affinis*, 67.5 mm in body-length (15.5 mm in carapace-length); *C* and *D*, *Mtapenaeus joyneri*, 97 (24); *E* and *F*, *Metapenaeus monoceros*, 102.5 (27.5); *G* and *H*, *Metapenaeus tenuipes*, 76 (18.5); *I–L*, *Metapenaeus intermedius*, 80 (20.5). *A*, *B*, *I*, and *J*, ×6; *C* and *D*, ×2.5; *E* and *F*, ×3.5; *G* and *H*, ×4; *K* and *L*, ×9.

tenellus, *P. cornutus*, *P. hungerfordi*, and *A. compressipes*, rather laterally compressed in *T. curvirostris* and *T. asper*, is of Type–PC_3 or Type–PC_4 in cross-section. Median lobe rather thickened, much narrower than lateral lobe. Lateral lobe furnished with an outstanding tubular projection pointed or truncate at tip, directed anteriorly or outward, on distal or disto-lateral border. Dorsal lobule of lateral lobe has a rather small projection directed outward in *P. tenellus*, backward in *P. fungerfordi*, posteromedially in *P. cornutus* and *A. compressipes*, inward in *T. curvirostris* and *T. asper* (Fig. 32).

Type–M_{11}: *Metapenaeopsis* belongs to this type. The petasma is considerably depressed, of Type–PC_5 in cross-section, consists of proximal and distal joints, has dorasally a deep longitudinal groove between

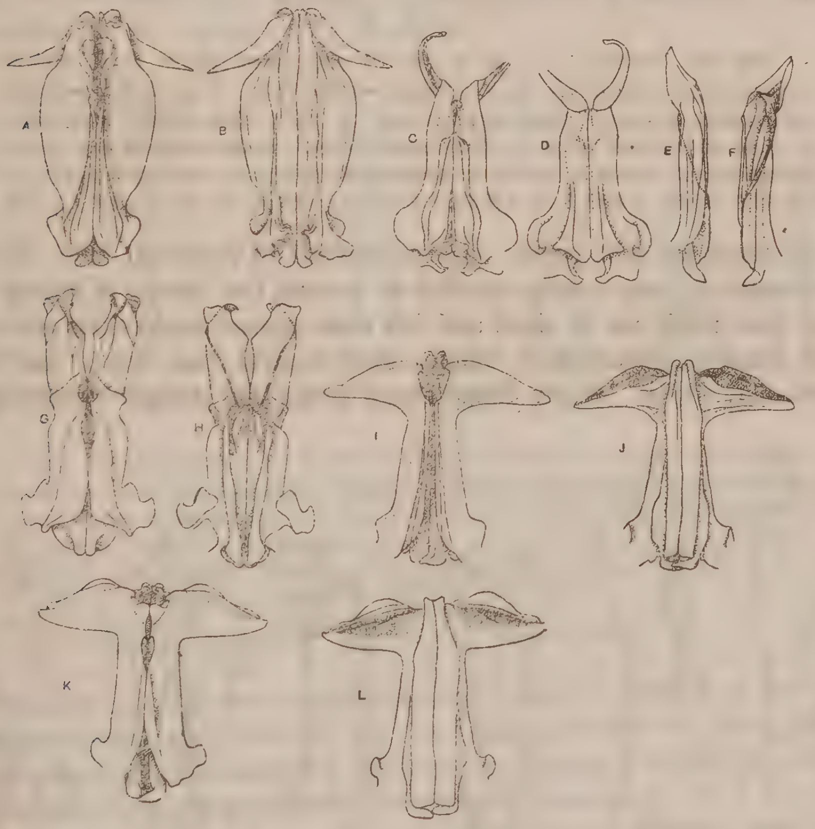

Fig. 32. Ventral (*A*, *C*, *E*, *G*, *I*, and *K*), and dorsal (*B*, *D*, *F*, *H*, *J*, and *L*) aspects of petasma referable to Type-M_{10}. *A* and *B*, *Parapenaeopsis tenellus*, 38 mm in body-length (9.5 mm in carapace-length); *C* and *D*, *Parapenaeopsis cornutus*, 84 (22.5); *E* and *F*, *Atypopenaeus compressipes*, 28 (8); *G* and *H*, *Parapenaeopsis hungerfordi*, 61 (17); *I* and *J*, *Trachypenaeus curvirostris*, 80 (23); *K* and *L*, *Trachypenaeus asper*, 61 (16). *A* and *B*, ×8.8; *C*, *D*, and *I*-*L*, ×4.8; *E* and *F*, ×16; *G* and *H*, ×8.4.

right and left ridges–*a*. Dorsal lobule of lateral lobe of right petasmal endopodite provided with a projection rounded at apex, directed postero-medially at posterior inner angle, that of left petasmal endopodite also has a similar projection at the same angle, but the projection of the latter is much longer than that of the right endopodite, extends far beyond median line of petasma, ventral free border of ventral lobule of lateral lobe of proximal joint gently curves outward in proximal half. Ridge–*c* rather marked, runs nearly parallel to ventral free border of lateral lobe. Distal joint made up of right and left disto-ventral projections and disto-dorsal lobules, distomedian lobule, disto-ventral flap, inner and outer intermediate strips. Right disto-ventral projection distally expanded and

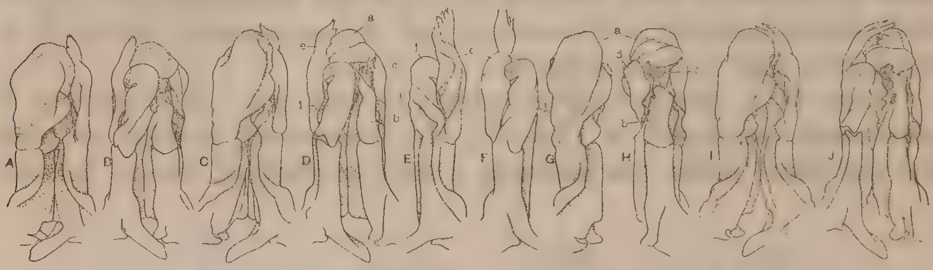

Fig. 33. Ventral (*A*, *C*, *E*, *G*, and *I*) and dorsal (*B*, *D*, *F*, *H*, and *J*) aspects of petasma (Type-M_{11}) of *Metapenaeopsis dalei*. *E* and *F*, left petasmal endopodite; *G* and *H*, right petasmal one. *a*, right disto-ventral projection; *b*, right disto-dorsal lobule; *c*, disto-median lobule; *d*, disto-ventral flap; *i*, left dorsal piece. *A* and *B*, 39 mm in body-length (9 mm in carapace-length); *C*–*H*, 45.5 (10.5); *I* and *J*, 70 (17.5). *A* and *B*, ×6.8; *C*–*H*, 6.4; *I* and *J*, ×4.8.

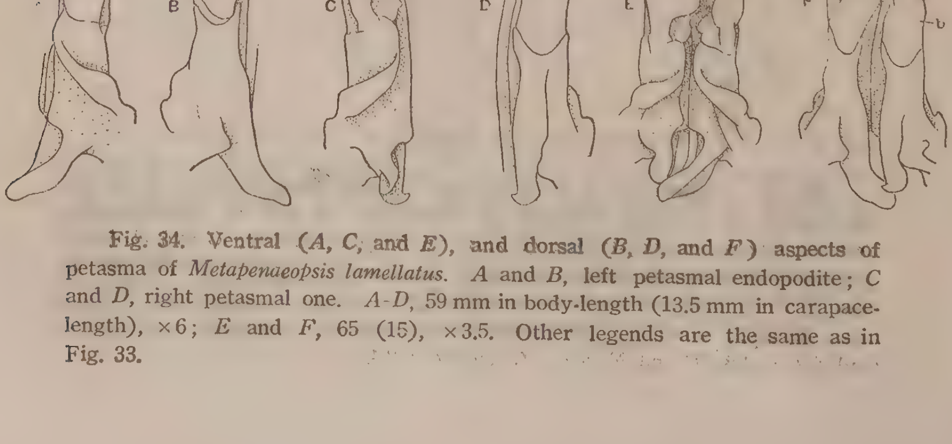

Fig. 34. Ventral (*A*, *C*, and *E*), and dorsal (*B*, *D*, and *F*) aspects of petasma of *Metapenaeopsis lamellatus*. *A* and *B*, left petasmal endopodite; *C* and *D*, right petasmal one. *A*-*D*, 59 mm in body-length (13.5 mm in carapace-length), ×6; *E* and *F*, 65 (15), ×3.5. Other legends are the same as in Fig. 33.

thickened with rounded apex, smooth on outer surface, usually furnished with a small number of apical spinules (Figs. 18 and 33–35, *a*). Right disto-dorsal lobule is smallest of all appendages of distal joint, thumb-like, extends as far as middle of right disto-ventral projection, uaually turns obliquely inwards in distal about one-third (Figs. 18 and 33–35, *b*). Disto-ventral flap thin, ribbon-like, sinistally coiled, as long as or somewhat shorter than right disto-ventral projection, usually covered by right and left disto-ventral projections, and inner and outer intermediate strips (Figs. 18, and 33–35, *d*). Left disto-ventral projection very similar to, but larger than, right disto-ventral projection, and carries larger number of apical spinules (Figs. 18, and 33–35, *e*). Left disto-dorsal lobule, inner and outer intermediate strips defined (Fig. 18, *f*–*h*) or fused as a rather slender outgrowth abruptly curved sidewise at apex (Figs. 33–35, *i*): defined in *Metapenaeopsis dulus*, *M. barbatus* and *M. acclivis;* fused in *M. lamellatus*, *M. coniger*, and *M. dalei*.

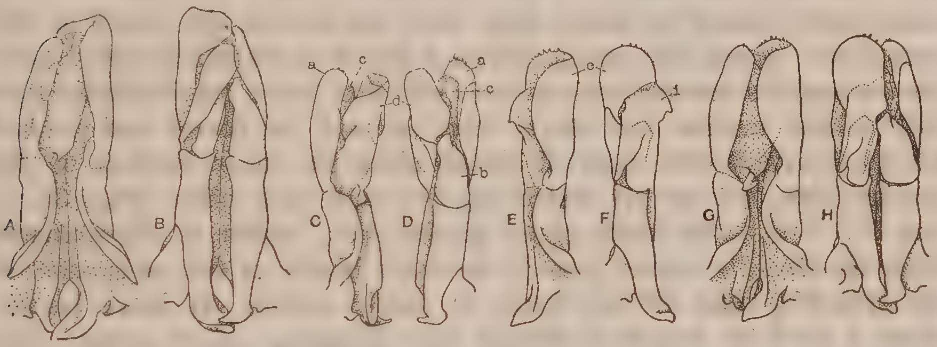

Fig. 35. Ventral (*A*, *C*, *E*, and *G*) and dorsal (*B*, *D*, *F*, and *H*) aspects of petasma of *Metapenaeopsis coniger*. *C* and *D*, right petasmal endopodite; *E* and *F*, left petasmal one. *A* and *B*, 48 mm in body-length; *C*–*F*, 58 mm in body-length (12 mm in carapace-length); *G* and *H*, 65.5 mm in body-length. *A* and *B*, ×10.5; *C*–*H*, ×6. Other legends are the same as in Fig. 33.

d. Metamorphosis of petasma of some species.

Requisite as it is, our knowledge of the metamorphosis of the male sexual appendage available for the exact interpretation of adult one and for understanding the natural relationship among subfamilies, genera, and species of the present family is altogether lacking.

A scrutiny was made by the present writer concerning the transformation of the organ of specimens of the species enumerated below which were gathered from various localities of Japan, viz., *Penaeus bubulus*, *P. monodon*, *Metapenaeus affinis*, *M. joyneri*, *M. monoceros*, *M. intermedius*, *Trachypenaeus curvirostris*, *Metapenaeopsis barbatus*, *M. acclivis*, *M. dalei*, *M. coniger*, *Atypopenaeus compressipes*, *Para-*

penaeopsis tenellus, *Parahaliporus sibogae*, *Aristaeomorpha foliacea*, *Aristaeus virilis*, and *Penaeopsis rectactus*.

Of the material listed above, the first nine respectively afforded rather complete series of the changes which occur during development and warranted the writer to make some comments on sounder basis.

1. Petasma of Type-M_2.

Parahaliporus sibogae. In a specimen, 60 mm in body-length, each of the petasmal endopodite is still ill-calcified, leafshaped in outline, about twice as long as wide measured at middle, not yet folded longitudinally, but provided with two apical strips already (Fig. 36, *A* and *B*). Inner border with no cincinnuli, strongly convex at about middle, and outer one also markedly convex near base. Apical strips are rather slender with rounded apex; inner lobule twice as long as wide, one-third the length of the endopodite; outer one shorter than inner lobule, somewhat longer than wide, one-seventh the length of the endopodite. When the animal attains a length of 92 mm in body-length, the endopodites covered with sparsely set setae, folded longitudinally with well defined median and lateral lobes as well as dorsal and ventral lobules, provided with many cincinnuli along the inner borders of the median lobes, but not yet united together with each other (Fig. 36, *C* and *D*). The dorsal lobule of the median lobe, which is difierentiated from the strongly convex part of the inner border of the endopodite of the preceding stage (60 mm long), is nearly convex on inner border, about a third the length of lateral lobe including apical strips. The ventral lobule of lateral lobe has a large auriculate projection near base. This projection is given off from the basal convex part of the outer border of the endopodite of the stage, 60 mm long. The distal two strips increases in size more than those of the preceding stage, although the apexes are still rounded. The inner strip measures about half the length of the lateral lobe, whilst the outer one is a little less than half.

The petasmal endopodite united with the opposite fellow at the time the animal measures about 100 mm long, and the petasma assumes its adult form.

Aristaeus virilis. In a specimen, 86 mm long, each of the petasmal endopodite is subrectangular with slightly convex anteromedian and outer, and wavy median borders, rounded at apex, clad with sparsely set short setae, but not yet folded longitudinally. The cincinnuli absent. A small appendage, which is rounded at apex directed forward, is present at four-fifths of the outer border (Fig. 36, *G* and *H*), moves proximally with advance of age, and found standing at about middle of the outer border in adult form.

The endopodite of a specimen, 94 mm in body-length, becomes more pubescent, somewhat narrowed distally, rounded at apex. The longitudinal folds well defined. The median and lateral lobes as well as dorsal and ventral lobules well differentiated. Numerous cincinnuli present along proximal half of the inner edge. The disto-lateral appendage gets markedly larger appearing as follows:—slender with truncate apex, five times as long as wide, well exceeded by apex of the endopodite (Fig. 36, *I* and *J*). In specimens larger than 100 mm in body-length, petasma reaches its adult form.

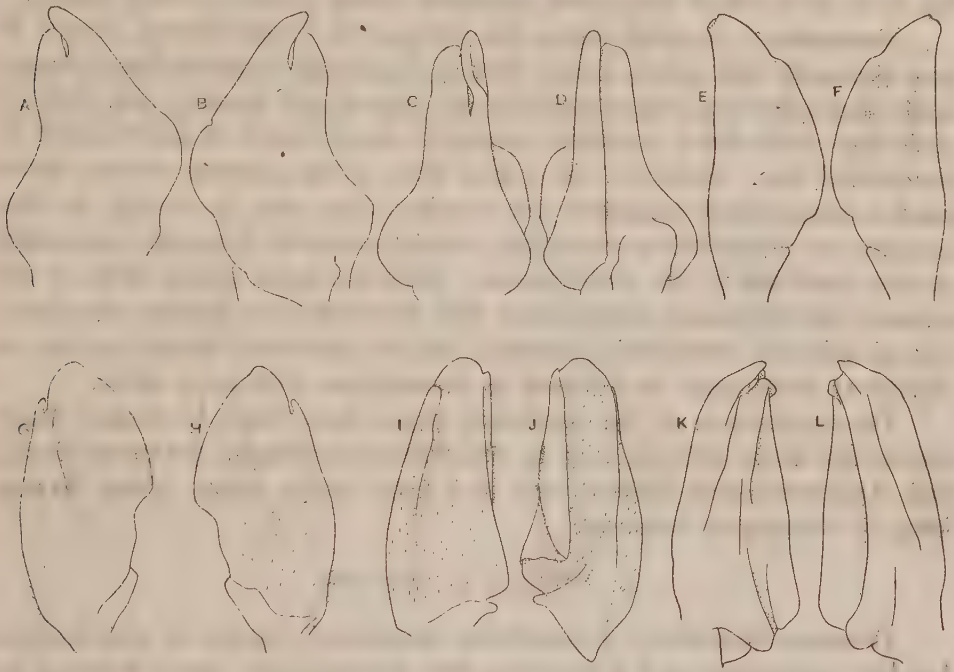

Fig. 36. Petasma of young form of *Parahaliporus sibogae* (*A–D*), *Aristaeomorpha foliacea* (*E* and *F*), *Aristaeus virilis* (*G–J*) and *Penaeopsis rectactus* (*K* and *L*). *A, C, E, G, J,* and *K*, ventral aspect. *B, D, F, H, I,* and *L*, dorsal aspect. *A* and *B*, 60 mm in body-length (16 mm in carapace-length) ×25; *C* and *D*, 93 (23), ×10.5; *E* and *F*, 83 (13), ×20; *G* and *H*, 86 (26); *I* and *J*, 92 (28), ×8. *K* and *L*, 60 (14), ×6.

Aristaeomorpha foliacea. At the time the prawn measures 83 mm long, each of the right and lefte petasmal endopodite is subcrescent in outline, rather suddenly curves disto-laterally at apex, with strongly convex inner border and almost straight outer one, truncate at apex, somewhat less than thrice as long as wide measured at middle. Longitudinal folds are hardly defined. The inner border is slightly indent at about four-fifths. The cincinnuli absent at all along the median border (Fig. 36, *E* and *F*). Probably the adult form is reached when the animal attains about 100 mm in body-length.

Penaeopsis rectactus. In a specimen, 60 mm long, petasmal endopodites are not yet knit together with each other, somewhat lunate in outline, with convex margin outward, folded longitudinally. The lobes and lobules, by which the endopodite is composed, are rather defined. The inner border of median lobe is still destitute of cincinnuli. The horn-like process, which is found on posterior border of dorsal lobule of lateral lobe of adult form, does not make its appearance yet. Disto-lateral spine of lateral lobe is less calcified, acute, and directed medially than that of adult form (Fig. 36, *K* and *L*). Perhaps the petasma attains its adult form when the prawn measures about 80 mm in body-length.

Remarks: In adult form, the petasma of *Parahaliporus sibogae* is provided with two apical strips, that of *Penaeopsis rectactus* has a strong acute spine directed antero-medially on disto-lateral border, and that of *Aristaeus virilis* has a spatulate process at about middle of outer border of the lateral lobe. However, the young form of the petasma of these three species considerably resembles one another, and also is slmilar to the petasma of *Miyadiella pedunculata*, which belongs to Type–M_1, especially in the condition of the distal strips. Thus the outer apical strip of the petasma of *Miyadiella pedunculata* and *Parahaliporus sibogae*, the disto-lateral spine of *Penaeopsis rectactus*, and the spatulate lateral process of *Aristaeus virilis* may be inferred as homologous with each other.

The adult form of the copulatory organ may reach to similar stage measuring about 100 mm long in *Parahaliporus sibogae*, *Aristaeus virilis*, and *Aristaeomorpha foliacea*, but at a little earlier stage, about 80 mm long, in *Penaeopsis rectactus*.

2. Petasma of Type–M_3.

Penaeus bubulus. A post-larva, measuring 13.9 mm in body-length, has the endopodite as a minute bud-like development, about 0.07 mm in length, with an apical hair (Fig. 37, *A*). It grows twice in length in a specimen, 16 mm in body-length (Fig. 37, *B*). In such specimens as 25.9–28.0 mm long, the endopodite increases in length from 0.3 mm to 0.5 mm, carries a bristle at about one-third of inner margin, and two or three setae on apical border, but undergoes no remarkable modification in general feature. The bristle set at about one-third of inner margin first appears when the animal attains a length of about 25 mm long, and persists until the animal reaches to about 45 mm in body-length (Fig. 37, *F*). Some marked change is found in the endopodite of a specimen, 42 mm long: the endopodite is subrectangular in outline in other part except for basal one quarter of it; proportion of length against width changes from five to four; the bristle laid down on the inner margin, shifts toward base, from one-third to one-fifth; and a broad notch is present on inner basal margin.

When the animal attains 52–53 mm in body-length, the endopodite is subrectangular in outline, measuring about one mm in length, provided with a sharply pointed disto-lateral spine which is directed forward and extends as far as distal lameller margin, but ratio of length against breadth is still 0.25 (Fig. 37, *G*, and *H*).

The endopodite of a specimen, 70.5 mm long, becomes ca. 1.6 mm in length and exhibits remarkable modification in general feature compared with that of the stage, 55 mm long: it shows spout-like aspect as the inner margin strongly recurves ventrally and medially; outer margin acutely turns out in distal one-third (Fig. 37, *I*).

As shown in Fig. 37, *J* and *K*, the petasmal endopodite of a specimen 82 mm in body-length measures ca. 3 mm in length, more or less resembles that of an adult form, althogh both the right and left lober

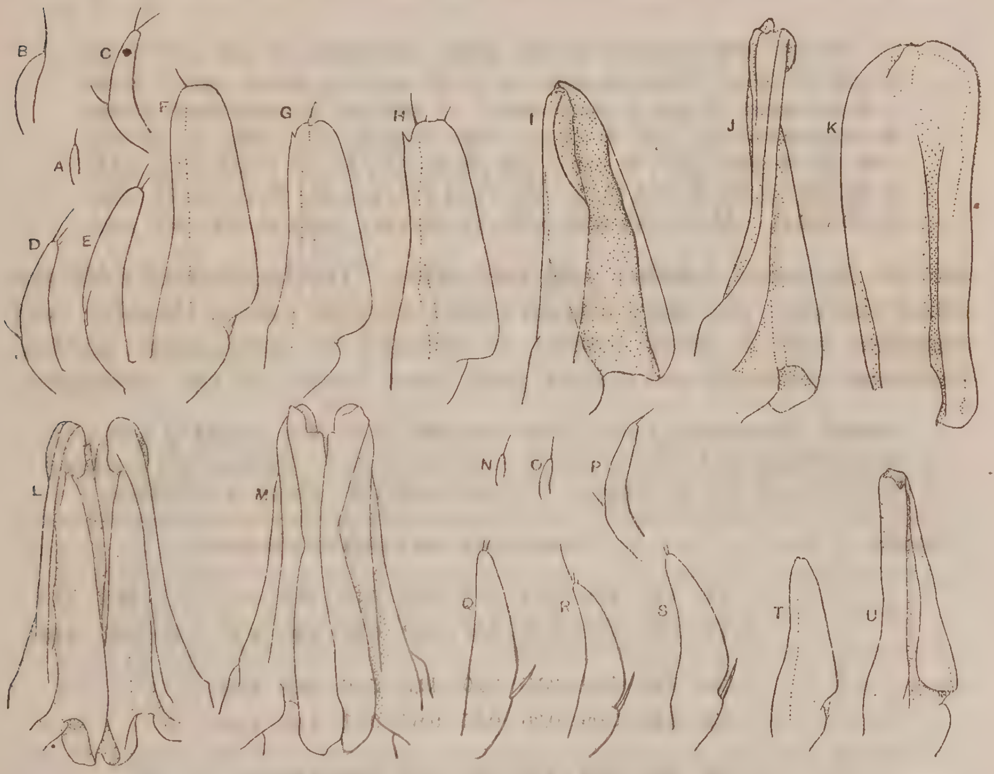

Fig. 37. Metamorphosis of first pleonic endopodite of male (*A–M*) and female (*N–U*) of *Penaeus bubulus*. *A–J*, *L*, *N–U*, ventral aspect; *K* and *M*, dorsal aspect; *J*, outer one. *A*, 13.9 mm in body-length, ×80; *B*, 16, ×80; *C*, 25.9, ×50; *D*, 27. ×50; *E*, 28, ×50; *F*, 42 mm in body-length (10 mm in carapace-length), ×50; *G*, 52 (13.5), ×35; *H*, 55 (15.5), ×35; *I*, 70.5 (21.5), ×25; *J* and *K*, 82 (27.6), ×15; *L* and *M*, 99 (28), ×10.5; *N*, 14, ×80; *O*, 16, ×80; *P*, 28.5, ×50; *Q*, 38 (10), ×50; *R*, 49 (13.5), ×35; *S*, 54.5 (16), ×35; *T*, 78 (22.5), ×25; *U*, 135 (38), ×20.

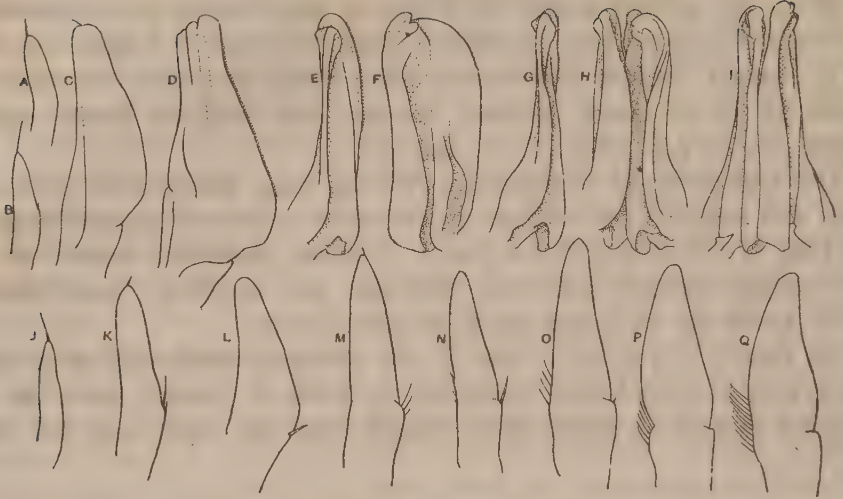

Fig. 38. Metamorphosis of first pleonic endopodite of male (*A–I*) and female (*J–Q*) of *Penaeus monodon*. *A–D*, *H*, and *J–Q*, ventral aspect; *F* and *I*, dorsal aspect; *E* and *G*, outer aspect. *A*, 24.7 mm in body-length (7 mm in carapace-length), ×60; *B*, 26 (7), ×60; *C*, 45.2 (12.5), ×40; *D*, 58 (15), ×28; *E*, 76 (20), ×8.8; *F* and *G*, 106 (27.5), ×6; *H* and *I*, 118 (31), ×4.8; *J*, 29 (7.5), ×60; *K*, 37.5 (9.5), ×60; *L*, 41 (11.1), ×40; *M*, 50 (13.2), ×40; *N*, 70 (18.4), ×28; *O*, 78 (20.5), ×28; *P*, 120 (31), ×16; *Q*, 174 (47), ×8.4.

are not yet united together with each other. The longitudinal folds are rather defined. The ohter margin rather abruptly curves dorsally, and furnished with a small number of spinules in subterminal portion. Numerous cincinnuli are present along inner border of the endopodite.

Table 9. Dimensions, in mm, of the endopodite of the first pleopod of both sexes of *Penaeus bubulus* (A), *Penaeus monodon* (B) and *Penaeus latisulcatus* (C) in relation to the body-length without rostrum. BL, body-length; EL, length of endopodite.

Species	Sex	Body-length and length of endopodite											
A	♂	BL	13.9	16.0	25.9	27.0	28.0	42.0	52.0	55.0	70.5	82.0	99.0
		EL	0.07	0.14	0.32	0.41	0.52	0.80	1.00	1.10	1.70	3.30	4.50
A	♀	BL	14.0	16.0	28.5	38.0	49.0	54.5	78.0	13.5			
		EL	0.05	0.06	0.36	0.55	0.65	0.71	1.00	1.90			
B	♂	BL	24.7	26.0	45.2	58.0	76.0	106.0	118.0				
		EL	0.25	0.25	0.82	1.28	3.63	5.26	6.91				
B	♀	BL	29.0	37.5	41.0	50.0	70.0	78.0	120.0	174.0			
		EL	0.28	0.43	0.71	0.74	0.95	1.14	1.85	3.52			
C	♂	BL	36.0	46.5	72.0	82.0	94.0						
		EL	0.44	1.31	3.63	4.24	5.66						

At the time the animal attains 99 mm in body-length, the petasma almost assumes the adult form and reaches a length of 4.5 mm (Fig. 37, *L* and *M*).

Remarks: similar metamorphosis of petasma is also observed in *Penaeus monodon,* and *Penaeus latisulcatus* (Figs. 38 and 39). But the relative length of petasma of *Penaeus bubulus,* as referred to the body-length, is considerably smaller than that of *P. monodon* and *P. latisulcatus* (Table 9). The difference is recognizable even in such young specimen as measuring about 60 mm in body-length.

The formation of petasmal channel of Type-M_3 takes place as follows:—the petasmal endopodite is lamellar, subrectangular in outline in the stage about 40 mm long in *P. latisulcatus,* about 50 mm long in *P. mondon* and *P. bubulus,* and then it gradually gets longitudinally folded twice proceeding from base to apex with somewhat w-shaped in cross-

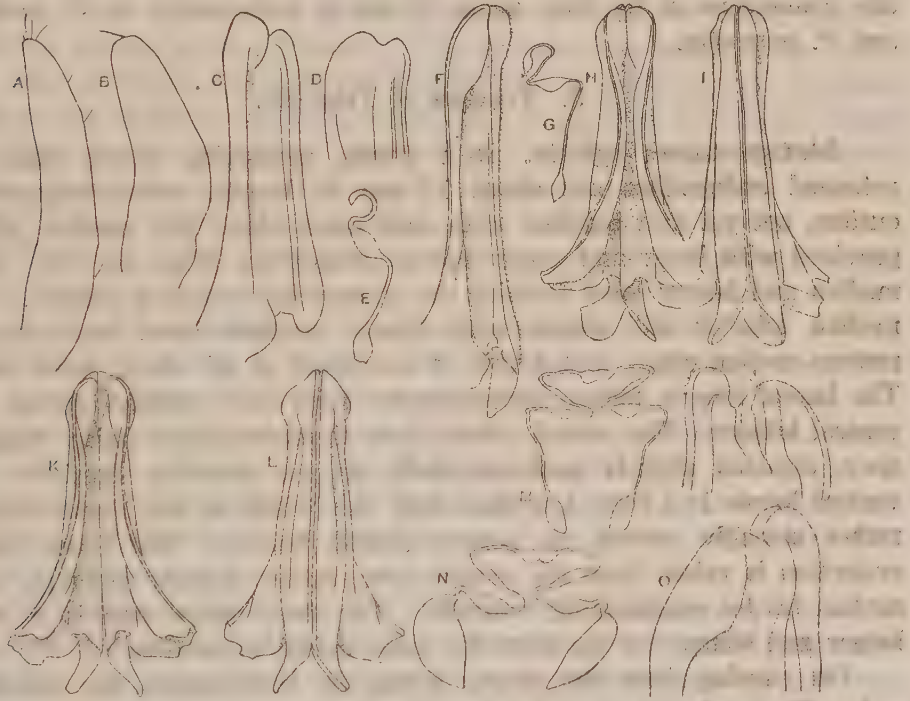

Fig. 39. Metamorphosis of first abdominal endopodite of female (*A*) and male (*B-O*) of *Penaeus latisulcatus.* *A C, F, H,* and *K,* ventral aspect; *E* and *L,* dorsal aspect; *D, J,* and *O,* lateral aspect of distal portion of the endopodite. *A,* 39.5 mm in body-length (10.5 mm in carapace-length), ×75; *B,* 36 (10.2), ×75; *C-D,* 46.5 (13), ×35; *D,* 25; *E,* cross-section at four-fifths of the endopodite, ×50; *F* and *G,* 72 (20.5); *F,* ×15, *G,* cross-section at three-fourths of the endopodite, ×25; *H-J,* 82 (23), ×10.5; *J,* ×20; *K-O,* 94 (26); *M,* cross-section at three-fourths of the endopodite, *N,* cross-section at one-fourth of the endopodite, *K* and *L,* ×7.5, and *M-O,* ×15.

section bearing dorsal and ventral free borders inward (Figs. 37, *J*, 38, *D–F*, and 39, *E–G*). When the prawns, *P. monodon*, 45.2 mm long (Fig. 38, *C*), and *P. latisulcatus*, 46.5 mm long (Fig. 39, *D*), petasma of these two species has a resemblance to that of *Miyadiella pedunculata*, although of a different type (Type–M_1), especially in the following respect. The apical border of the endopodite of the three species of *Penaeus* in question is considerably or slightly emarginate at apex.

In an early stage, the petasmal endopodite or first pleonic endopodite attains a length of ca. 80 mm long in *P. latisulcatus*, ca. 100 mm in two others. The channel is completed after the distalward fusing of both the right and left endopodites along their inner margins.

Remarkably enough, the petasmal endopodite of a young form of *P. bubulus*, 52 mm long (Fig. 37, *G*), and *P. monodon*, 45.2 mm of male closely resembles the corresponding endopodite of female in general configuration. As shown in Figs. 37–39, sexual dimorphism of the endopodite commences at the time about 40 mm in body-length in *P. bubulus* and *P. monodon*.

3. Petasma of Type–M_9.

Metapenaeus affinis. In a young, measuring 28 mm long, the petasmal endopodites are about 1.1 mm in length, subrectangular in outline, not yet knit together with each other along the median edges, provided with inner and outer apical projections (Fig. 40, *A*). Both median and lateral lobes forming the endopodite are rather defined. The median lobe is still simple with almost straight inner and rounded postero-median edges, and devoid of cincinnuli at all along inner edge. The lateral lobe is folded longitudinally with well defined dorsal and ventral lobules. The dorsal lobule has a protuberance with rounded apex, directed slightly posteromedially on the posterior border. The ventral lobule is a little less than half the width of the dorsal lobule, rather strongly convex on postero-median border. The inner apical projection is raised from the median lobe, rather acutely pointed, with median border overhanging ventrally. The outer apical one is a little longer and sharper at tip than the inner apical projection.

On passing into the stage, 36 mm in body-length, the petasmal endopodite is about twice the length of that of the preceding stage, 28 mm long, nine times as long as wide (Fig. 40, *B* and *C*). The median lobe is well defined in proximal two-thirds, furnished with many cincinnuli along inner border. The ventral lobule of the lateral lobe extends as far as inner border of the median lobe; distal border is straight, runs antero-laterally; proximal one gently curves sidewise. The inner apical projection gets somewhat slenderer, tubular, and directed antero-laterally. The outer apical projection trough-like with somewhat U-shaped cross-section and rounded apex, as the disto-median border of the ventral lobule of the lateral lobe completely overlaps its ventral surface. The protuberance laid down on posterior border of dorsal lobule of the lateral lobe is markedly expanded with circularly rounded apex directed inward. The ridge–*a* is well defined, more or less expanded at about middle with outer rim hardly reaching to the lateral border of the lateral lobe (Fig. 40, *B*).

As illustrated in Fig. 40, *D* and *E*, the petasmal endopodites of a male, 45.5 mm long, are united together with each other in proximal ca. two-thirds, about 3.3 mm and 1 mm in length and width respectively. The distal border of ventral lobule of lateral lobe is still almost straight lying antero-laterally; the proximal one curves a little more strongly outward. The inner apical projection is hood-like in outline with free margins sidewise, directed obliquely outward. extending as far as the outer apical projection, armed with a small number of setae along disto-ventral border. The outer apical projection is round at apex, notched at about middle of dorsal border. The protuberance raised from posterior edge of dorsal lobule of the lateral lobe is considerably increased in size, but shows no marked modification in general feature compared with that of the preceding stage, 36 mm in body-length. The outer border of the expanded portion of the ridge–*a* extends as far sidewise as the lateral border of the petasma.

The adult form of petasma seems to be reached during such stages as 50–60 mm in body-length.

In an adult specimen, 67.5 mm long, the petasma measures 7.5 mm in length, and 2.5 mm in width. The inner apical projection is one and half times as long as wide, and one-fifth as long as the petasma, and resembles a sort of hood in shape as is the case with that of the stage, 45.5 mm long. The outer apical projection is one-eighth the length of the petasma, directed laterally at right angles. The protuberances given off from posterior border of dorsal lobule of the lateral lobe come into contact with each other.

Metapenaeus joyneri. A juvenile, 40 mm long. has a pair of petasmal endopodites not conjoined yet, each of which is subrectangular in outline with two apical projections and a protuberance on proximal border as in that of *Metapenaeus affinis*, 1.8 mm in length and 0.3 mm in width (Fig. 40, *F* and *G*). The median lobe is defined in proximal three-fourths, with no cincinnuli along median border. The lateral lobe is provided along the outer border of ventral surface with a longitudinal swelling, from which the ventral lobule of this lobe develops. The apical projections closely resemble those of the petasma of *M. affinis*, inner one of which is much smaller than the other. Protuberance found on the proximal border is papilla-like, directed postero-medially.

A little advanced stage with a body-length of 55 mm, the endopodite is 4.3 mm in length and 0.7 mm in breadth. Median lobe is well defined, rather abruptly narrowed in its subterminal portion and reaches to

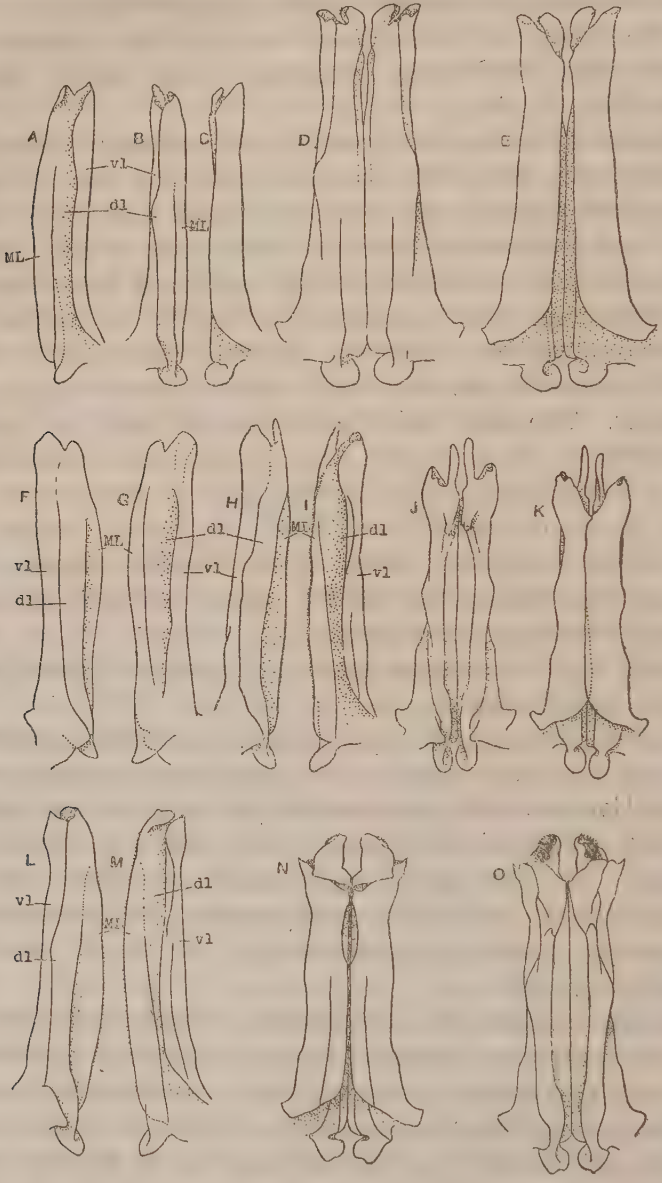

Fig. 40. Showing transformation of petasma of *Metapenaeus affinis* (*A–E*), *Metapenaeus joyneri* (*F–K*), and *Metapenaeus monoceros* (*L–O*). *A, C, E, G, I, K, M,* and *N,* ventral aspect; *B, D, F, H, J, L,* and *O,* dorsal aspect. *dl,* dorsal lobule; *ML,* median lobe; *vl,* ventral lobule. *A,* 28 mm in body-length (7 mm in carapace-length); ×35; *B* and *C,* 36 (9), ×20; *D* and *E,* 45.5 (11), ×15; *F* and *G,* 40 (11), ×25; *H* and *I,* 55 (13.5), ×11.5; *J* and *K,* 75 (18.5), ×6; *L* and *M,* 62 (16.5), ×11; *N* and *O,* 75 (20), ×6.

about five-sixths of the median border of the endopodite, provided with numerous cincinnuli along almost entire inner border. With regard to lateral lobe, the dorsal lobule undergoes no marked modification in feature. But the ventral lobule is greatly developed arising ventro-medially from the longitudinal swelling laid down along the outer border of the lateral lobe of the preceding stage, 40 mm long, and overlaps about half of the dorsal lobule, with median border almost straight and proximal one gently sloping sidewise as in *Metapenaeus affinis*. A remarkable metamorphosis occurs in the apical projections. The inner apical projection appears straight, directed anteriorly, very slender, and measures about one-ninth as long as the endopodite somewhat exceeds the tip of the other apical projection. The outer apical projection gets somewhat trough-like as the distal border of the ventral lobule of the lateral lobe overlaps about half of its ventral surface. The protuberance set on the proximal border of the dorsal lobule of the lateral lobe becomes somewhat spatulate with rounded apex directed postero-medially.

At a stage, 75 mm in body-length the right and left petasmal endopodites come into contact with each other along median edges (Fig. 40, *J* and *K*). The petasma takes a length of about 5.5 mm measured from proximal border to distal one, is a little more than quadruple as long as wide. The inner apical projection is still straight, rounded at apex, but much increased in length, measures about one-fifth the length of petasma except the proximal protuberances, and reaches beyond apex of the outer projection by about half. The outer apical projection becomes almost completely tubular assuming the outline of a papilla, basally a trifle swollen, directed a little antero-laterally. Each protuberance which lies on the proximal border of dorsal lobule of lateral lobe is considerably expanded compared with that of the preceding stage, 55 mm long, but not yet comes into contact with each other. The outer rim of the ridge-*a* is markedly dilated already at about middle extending a little beyond outer rim of the petasma.

At the time prawn attains about 88 mm in body-length, the apparatus in question takes its adult form, mainly differs from that of the preceding stage, 75 mm long, in the respects given below. The inner apical projection is strikingly elongated, pointed at apex, makes a strong hook recurving dorsally and backward. The outer apical projection is greatly shorter than the inner apical one. The proximal protuberances of dorsal lobules of the lateral lobes overlap with each other on median border.

Metapenaeus monoceros. Each component of endopodite of petasma of a young male, 62 mm long, measures ca. 4 mm in length, about one-fifth as wide as long, closely resembles that of *Metapenaeus affinis* and *M. joyneri* in general aspect (Fig. 40, *L* and *M*). The median lobe is defined, reaching to about four-fifths of the inner border of the endopodite, like that of the stage, 55 mm long, of *Metapenaeus joyneri*, furnished with many cincinnuli along inner margin. The ventral lobule of the lateral lobe is considerably developed overlapping about half of ventral surface of the dorsal lobule of the lateral lobe, has proximal edge gently sloping laterally. The inner apical projection is yet simply lamellar with rounded apex, directed sidewise, overhanging, ventral surface of the dorsal lobule (on which it lies) of the lateral lobe. The outer apical projection somewhat trough-like with rounded distal edge, slightly shorter than the inner apical projection, made up of dorsal and ventral walls. The dorsal wall originated from the dorsal lobule of the lateral lobe, and the other wall from the ventral lobule of the lateral one. The protuberance attached to the proximal border of the dorsal lobule of the lateral lobe is considerably pronounced, ogival in outline, directed posteromedially.

On reaching the stage, 75 mm long, both right and left petasmal endopodites are already firmly coupled together with each other along the median rim (Fig. 40, *N* and *O*). The petasma nearly assumes its adult form in general configuration, measures ca. 7 mm and 2 mm in length and width respectively. The median lobe reaches to apex of the petasma, but greatly constricted in distal about one-fifth. The inner border of dorsal lobule of the lateral lobe extends to about the median line of the petasma. The inner apical projection is pod-like, directed forward, about a fifth the length of the dorsal lobule of the lateral lobe, one and half times as long as wide measured near base, dorsally has a gap, provided with a number of setae along dorsal disto-lateral border; the proximal edge is almost straight, runs slightly antero-laterally; the proximo-lateral angle somewhat overlaps the distal fringe of the ventral lobule of the lateral lobe. The outer apical projection is trough-like, sharply pointed at tip, directed antero-laterally, greatly exceeded by the inner apical projection. The posterior protuberances of dorsal lobules of the lateral lobes are much increased in size, with somewhat emarginate postero-median border, still separated from each other by a considerable gap. The ridge-*a* is dilated at about middle with outer edge extending as far as the outer border of the petasma. The ridge-*c* is defined in proximal about half.

During the stages, 90–100 mm in body-length, the petasma attains almost full development. The petasma of an adult, 102.2 mm long, measures about 14 mm and 4 mm in length and width respectively. (Fig. 31, *E* and *F*). Remarkable differences of the organ compared with that of the stage, 75 mm in body-length, are found in three points: the inner apical projection, the protuberance lying on the posterior border of the dorsal lobule of the lateral lobe, and the ridge-*c*. The inner apical projection is triangular in outline, 1.3 times as long as wide measured along its ventral proximal border, one-third the length of the petasma except the posterior protuberances; the dorsal gap is greatly narrowed or entirely closed; the postero-ventral margin is almost transverse to the median axis of the petasma; the ventral postero-lateral angle is sharply pointed, considerably surmounts the outer border of the outer apical projection; the setae set along subterminal outer edge somewhat increase in number. The posterior protuberance of the dorsal lobule of the lateral lobe is more strongly notched on postero-median border. The ridge-*c* extends to about four-fifths of the ventral lobule of the lateral lobe.

Metapenaeus intermedius. In a young, 66 mm body-length, the petasmal endopodites are connected already in distal two-thirds of the median border (Fig. 31, *K* and *L*). The petasma is subrectangular in outline as in *Metapenaeus affinis*, *M. joyneri*, and *M. monoceros*, bearing inner and outer apical projections, and dorsal lobule of lateral lobe with a protuberance on posterior border, and measures 4.4 mm in length and 1.2 mm in width. The inner apical projection is spout-like with dorsal and ventral walls, U-shaped in cross-section, triangular in outline bearing somewhat convex closed border anteromedially, open posteriorly and laterally. The ventral wall has posterior edge slightly concave running sidewise, is subrectangular at postero-lateral corner which stretches to or slightly overlaps disto-median border of the dorsal lobule of the lateral lobe. The outer apical projection is also spout-like, sharply pointed at tip, directed antero-laterally near middle of the outer border, provided with a ω-shaped notch at the middle of the dorsal median edge and a semicircular one on the ventro-median border opposite the ω-shaped notch. The protuberance placed on posterior border of the dorsal lobule of the lateral lobe is considerably developed already, directed postero-medially, rounded at apex, somewhat indent on postero-median border. The ridge-*a* is markedly expanded sidewise at the middle extending as far outward as the lateral edge of the petasma. The ridge-*c* is defined in about proximal one-third.

In the stage, 80 mm in body-length, the petasma is entirely united along median line, ca. 6.2 mm in length and 1.9 in breadth. Both the apical projections are much increased in size, and directed a little more outward, but undergo slight modification in general feature. The inner apical projection is a little shorter than wide measured along ventral posterior border which is straight running slightly antero-laterally, the postero-lateral angle attains about the middle of the ventral surface of the outer apical projection. The ω-shaped notch of the dorsal antero-median edge of the outer apical projection becomes asymmetrical as the distal branch of the notch gets greatly larger than the proximal one.

The semicircular notch found on the ventral antero-median border of the apical projection is completely overlapped by the disto-lateral portion of the ventral wall of the inner apical projection. The posterior protuberance attached to the dorsal lobule of the lateral lobe is more expanded. The outer margin of the markedly expanded portion of the ridge-*a* reaches considerably beyond the outer edge of the petasma, so that it is observable from ventral side of the petasma.

Remarks: The median lobe of the petasma is observed already well defined in the stage, 28 mm long in *Metapenaeus affinis*, 40 mm long in *M. joyneri*, and 62 mm long in *M. monoceros*. This lobe does not reach to apex of the petasmal endopodite in such early stage as 55 mm in *M. joyneri* (Fig. 40, *H* and *I*) and 62 mm long in *M. monoceros* (Fig. 40, *L* and *M*). But it is evident that the lobe gradually extends forward with advance of age and reaches to inner base of the inner apical projection as a greatly constricted lobe. This condition is clearly observable in young form of the three species of *Metapenaeus* given above and even in adult forms of *M. joyneri* and *M. monoceros*. Thus there is no room for doubt that the inner and outer apical projections are not originated from the median lobe, but given rise to from the lateral lobe.

The mode of the development of ventral lobule of the lateral lobe is unique throughout all the following three species: *M. affinis*, *M. joyneri* and *M. monoceros*, but essentially differs from that of *Penaeus bubulus*, *P. monodon* and *P. latisulcatus*. The incipient condition is found in a specimen, 40 mm in body-length, of *M. joyneri* (Fig. 40, *G*). At first the fundament makes its appearance as a longitudinal swelling which runs along the outer border of the lateral lobe. This swelling gradually grows ventro-medially, and reaches to about the middle of ventral surface of the lateral lobe at the stages, 28 mm long in *M. affinis*, 55 mm long in *M. joyneri*, and 66 mm long in *M. monoceros* (Fig. 40, *A*, *I*, and *M*). At last it extends as far as the median line of the petasma.

The category of formation of the outer apital projection of *M. affinis*, *M. joyneri*, *M. monoceros*, and *M. intermedius* is entirely similar. That of the inner hood-like apical projection of *M. affinis*, *M. monoceros* and *M. intermedius* is more intricate than that of the simply hook-like one of *M. joyneri*.

In early stage, the petasmal endopodite of *M. affinis*, *M. joyneri* and *M. monoceros* is very similar to that of Type-M_1 and Type-M_2, especially in having two laminar projections on apical border. This fact compels the writer to consider that the petasma of Type-M_8 (*Metapenaeus*) is evolved through an ancestral type like Type-M_1 as is the case with that of Type-M_2.

Finally it should be noticed that combination of the petasmal endopodites seems to occur somewhat before the prawn attains a length of 45.5 mm in body-length in *M. affinis*, 75 mm in *M. joyneri* and *M. monoceros*, and 66 mm in *M. intermedius*. The petasma may assume its adult form at a stage measuring about 55 mm in *M. affinis*, 90 mm in *M. joyneri*, *M. moneceros* and *M. intermedius*.

4. Petasma of Type-M_{10}.

Trachypenaeus curvirostris. In a specimen measuring 20 mm in body-length, the petasmal endopodite is about 0.8 mm in length, inverted boot-shaped in outline, a little less than five times as long as wide measured at middle (Fig. 41, *A* and *B*). Median lobe is hardly differentiated as a narrow longitudinal area, destitute of cincinnuli along inner edge. Dorsal and ventral lobules of lateral lobe are well defined already as folded longitudinally along the boundary between the lobules, with v-shaped cross-section. The lateral lobe gives off a wing more or

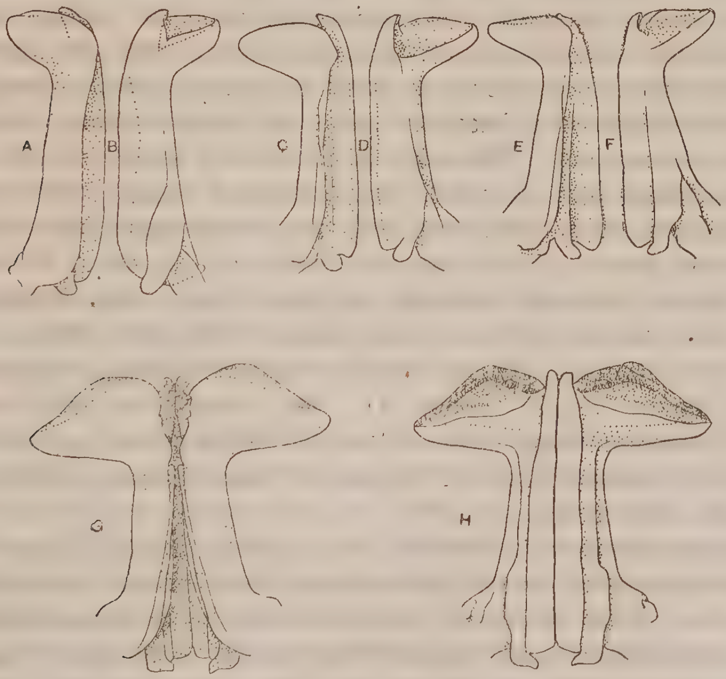

Fig. 41. Metamorphosis of petasma of *Trachypenaeus curvirostris*. *A*, *C*, *E*, and *G*, ventral aspect; *B*, *D*, *F*, and *H*, dorsal aspect. *A* and *B*, 20 mm in body-length (6 mm in carapace-length), ×50; *C*, and *D*, 25 (8), ×35; *E* and *F*, 34 (9), ×25; *G* and *H*, 37 (9.5), ×15.

less narrowed distally with rounded apex directed sidewise from the disto-lateral border. The wing is as long as wide measured at base, about one-fifth the length of the petasmal endopodite, made up of upper and lower lobes united along posterior and apical borders. The upper lobe raised from the dorsal lobule of the lateral lobe, and the lower lobe from the ventral lobule. The dorsal lobule of the lateral lobe distally continues to a small outgrowth which is directed antero-laterally, extends a trifle beyond distal rim of the wing; has a protuberance with rounded apex directed somewhat medially on the proximal border.

At the stage, 25 mm long, the endopodite (Fig. 41, *B* and *C*) is about 1 mm in length, shows no marked transformation compared with that of the stage, 20 mm long, quadruple as long as wide measured at middle. The median lobe is more defined, but not yet provided with cincinnuli along inner border. The distal median process gets a little more developed. The wing is a quarter the length of the appendage.

In a specimen, 34 mm long, the endopodite measures about 1.3 mm in length, does not differ in general feature from that of the stage, 25 mm in body-length except the annexed points: the protuberance put on proximal border of the dorsal lobule of the lateral lobe becomes a little slenderer, more strongly directed inward, and the median border is furnished with many cincinnuli in proximal and distal one-quarter.

When the animal reaches to about 37 mm long, the petasma almost assumes its adult form, becomes twice in length against that of the specimen, 34 mm long. The wing is a third the length of the petasma instead of about half in adult form, becomes ragged with numerous short fine setae in anterior marginal area of the upper and lower lobes. The process present on the posterior border of the dorsal lobule of the lateral lobe is increased in length, pointed at tip, rightangulary curves inward, but does not yet come into contact with each other.

In an adult form, 80 mm in body-length, the petasma measures about 6 mm in length (Fig. 32, *I* and *J*). The wing gets rather slenderer, about 0.4 times as long as the petasma. The processes set on posterior border of the dorsal lobule of the lateral lobes became a little overlapping each other at tip.

***Parapenaeopsis tenellus*:** In a young male, 21 mm long, the petasmal endopodites are not yet conjointed together with each other, measures about 1.5 mm in length, 5 times as long as wide measured at midway, less swollen on outer border than that of adult form (Fig. 134, *A* and *B*). Median lobe is differentiated as a narrow lobe with many cincinnuli along the inner border. Lateral lobe folded longitudinally with v-shaped cross-section, provided with a horn-like disto-lateral projection pointed at apex, directed postero-laterally. The horn-like projection is about one-third the length of the endopodite, consists of upper and lower lobules. The upper lobule raised from the dorsal lobules of the lateral lobe, the lower one from the ventral lobule of the lateral lobe as in *Tranchynaeus curvirostris*. But the projection is channeled dorsally with c-shaped cross-section bearing rather broad gap as the upper lobule is much narrower than the lower lobule and the anterior border of the lower one recurves dorsally and posteriorly. The gap of the channel becomes gradully narrower with advance of age, and entirely closed in the adult form. The petasma probably gains its adult form at the time the shrimp attains to about 30 mm in body-length.

***Atypopenaeus compressipes*:** The petasma of a specimen, 28 mm long, which is the smallest male dealt with, is not united along inner border of each petasmal endopodite yet (Fig. 32, *E* and *F*). Each endopodite measures about 1.5 mm in length excluding both proximal and distal projections, 0.24 mm in width, furnished with a large tubular horn at apex and a pointed protuberance directed postero-medially on posterior border of dorsal lobule of lateral lobe. Median lobe is rather defined, has a series of cincinnuli along inner border, but its dorsal and ventral lobules are not differentiated. Median lobe and dorsal lobule of lateral lobe is yet recurved dorsally in distal about half, but they gradually turn inward with advance of age. The apical tubular horn originated from the lateral lobe as in *Trachypenaeus curvirostris* and *Parapenaeopsis tenellus*, triangular in outline, directed antero-laterally, armed with two or three spinules at apex, dorsally has a triangular gap in proximal half. But this horn shifts successively turning inward with dorsally recurved portion of the median lobule and dorsal lobule of the lateral lobe, and the triangular gap gets gradually narrower with advance of age.

In an adult male, 39 mm long, the petasma measures about 2 mm and 0.7 mm length and breadth respectively. The apical horn is completely closed and directed forward (KUBO, 1936, p. 58, pl. 16. Fig. *C* and *D*).

Remarks: Summarizing above, it is stated without doubt that the outstanding distal projections of the petasma of *Trachypenaeus curvirostris, Atypopenaeus compressipes* and *Parapenaeopsis tenellus* are equal at all in the following facts: the projections consist of dorsal and ventral walls; the dorsal is raised from the dorsal lobule of the lateral lobe, and the ventral one from the ventral lobule of the lateral one.

Of the three species: *Parapenaeopsis cornutus, Parapenaeopsis hungerfordi* and *Trachypenaeus asper*, all of which belong to Type-M_{10}, nothing of the metamorphosis of the petasma has been known. But the writer is compelled to regard that the outstanding distal projections of the petasma of these three species are formed by the same pattern as that of *T. curvirostris, P. tenellus*, and *A. compressipes*, after minute observation of the petasma of adult *P. cornutus*, *P. fungerfordi*, and *T. asper*.

Moreover, interest attaches to the point that the distal projection of *T. curvirostris*, *P. tenellus*. and *A. compressipes* is homologous with, and equal in essential mode of formation of, the apical outer projection of *Metapenaeus affinis*, *M. joyneri*, *M. monoceros*, and *M. intermedius*.

Finally it is worth mentioning that the formation of the ventral lobvle of the lateral lobe of *Trachypenaeus curvirostris* is the same in manner as that of *M. affinis*, *M. monoceros*, and *M. joyneri*, judging from the early condition of the petasmal endopodite of *T. curvirostris*. As set forth already, the ventral lobule of *T. curvirostris* of such early stages, 20–34 mm in body-length, is found raised ventro-medially with v-shaped cross-section extending as far as the middle of the dorsal lobule of the lateral lobe (Fig. 41, *A*, *C*, and *E*), as in that of early stage, 28 mm long in *M. affinis*, 55 mm long in *M. joyneri*, and 62 mm long in *M. monoceros*.

5. Petasma of Type–M_{11}.

***Metapenaeopsis barbatus*.** In a larval specimen, 19.5 mm long, the right and left petasmal endopodites are similar in size measuring about 0.62 mm in length, and 0.12 mm in width, but are asymmetrical in feature at apex, The articulation lying between proximal and distal pieces is hardly recognizable. In the right endopodite (Fig. 42, *C* and *D*), the proximal piece is simply lamellar, flattish on dorsal and ventral surfaces, subrectangular in outline, about quadruple as long as wide; proximal border runs obliquely outward, with a notch at about middle. The distal piece is made up of two lobes which are much different in size. The smaller lobe, which is rudiment of the right disto-ventral projection, is thumblike, rounded at apex, directed forward, twice as long as wide, about a quarter the length of the proximal piece, situated on distal outer border of proximal piece (Fig. 42, *C* and *D*, *a*). The larger one is a little more than half the length of the proximal piece, provided along entire disto-median border with three lobules which are rounded at apex, and increase in size toward tip. As regards the three lobules, the proximal lobule (Fig. 42, *C* and *D*, *b*) develops into the right disto-dorsal lobule, the intermediate (Fig. 42, *C* and *D*, *c*) into the disto-median lobule, and the distal (Fig. 42, *C* and *D*, *d*) into the disto-ventral flap. In the left endopodite (Fig. 42, *A* and *B*), the proximal piece is almost equal to that of the right endopodite in general aspect. The distal piece is also composed of large and small lobes as in that of the right endopodite. Of these two lobes, the smaller one, which develops into left disto-ventral projection, is very similar to that of the distal piece of the right endopodite in general configuration (Fig. 42, *A* and *B*, *e*). The larger lobe is somewhat shorter than that of the distal piece of the right endopodite, and has inner and outer lobules on apical border. The inner lobule is convex on distal border, and grows into the inner intermediate strip (Fig. 42, *A* and *B*, *g*). The outer lobule is bluntly pointed at apex and extends somewhat beyond tip of the inner lobule, being afterwards transformed to the outer intermediate strip (Fig. 42, *A* and *B*, *h*).

On reaching a stage, 30.5 mm in body-length, the endopodite measures ca. 1.2 mm in total length, and exhibits remarkable asymmetry, especially in the distal piece (Fig. 42, *E–H*). The median lobe is well defined, and provided with many cincinnuli along distal one-third of the inner border. The lateral lobe is markedly thickened. The proximal piece of the right endopodite is about 1.7 times as long as that of the left endopodite of the stage, 19.5 mm long, furnished with a short pointed and medially directed protuberance on postero-median border of the dorsal lobule of lateral lobe. The distal piece is much modified in shape of the elements, by which the piece is composed. The disto-ventral projection becomes very slender and lanceolate, and is about six times as long as wide, about two-thirds the length of the proximal piece (Fig. 42, *G* and *H*, *a*). The right disto-dorsal lobule and the distomedian lobule undergo no marked modification yet being similar in feature with each other, and much wider than long (Fig. 42, *G* and *H*, *b* and *c*). The disto-ventral flap is tongue-like in outline, somewhat twisted inward, rounded at apex directed antero-medially (Fig. 42, *G* and *H*, *d*). The proximal piece of the left endopodite closely resembles that of the right endopodite except that the papilla-like protuberance laid down on the postero-median border of the dorsal lobule of the lateral lobe is much larger than that of the right endopodite. The left disto-ventral projection appears lanceolate in outline like the right distro-ventral projection, but considerably larger and longer than the projection in question, and provided with one or two spinules at apex (Fig. 42, *E* and *F*, *c*). The left disto-dorsal lobule is subrectangular in outline, about half as long as the proximal piece of the left disto-ventral projection. Both the inner and outer intermediate strips are still vestigial, lying on distal border of the left disto-dorsal lobule as protuberances with rounded apices (Fig. 42, *E* and *F*, *g* and *h*).

In a specimen with 44 mm long, the right endopodite measures 3.2 mm in length. The proximal piece is about 2 mm in length. The ventral lobule has the inner border arcuate running gently outward in proximal half. The ridge–*a* is well developed, and the ridge–*c* defined posterior to about the middle of the proximal piece of the right endopodite. The right disto-ventral projection gets thickened, broad, concavo-convex with convex surface sidewise, smooth on outer surface, and abruptly pointed at apex, extending as far as the disto-ventral flap, about two-thirds the length of the proximal piece of the right endopodite. The right disto-dorsal lobule is ogival in outline, reaching a little beyond the half-way of the right disto-ventral projection, somewhat more than twice as long as wide measured at base. The disto-median lobule rather slender, embraced by the right disto-ventral projection, extends beyond tip of the right disto-dorsal lobule by about half. The disto-ventral flap is membranous, ribbon-like, spirally rolled in distal half. A narrow gap lies antero-medially between the distoventral flap and the disto-dorsal lobule (Fig. 42, *K* and *L*). The protuberance attached to proximo-median border of the dorsal lobule of the left lateral lobe is remarkably lengthened, about half the length of the proximal piece of the left endopodite, bluntly pointed at apex and directed slightly postero-medially. The left distoventral projection is concavo-convex with concave surface

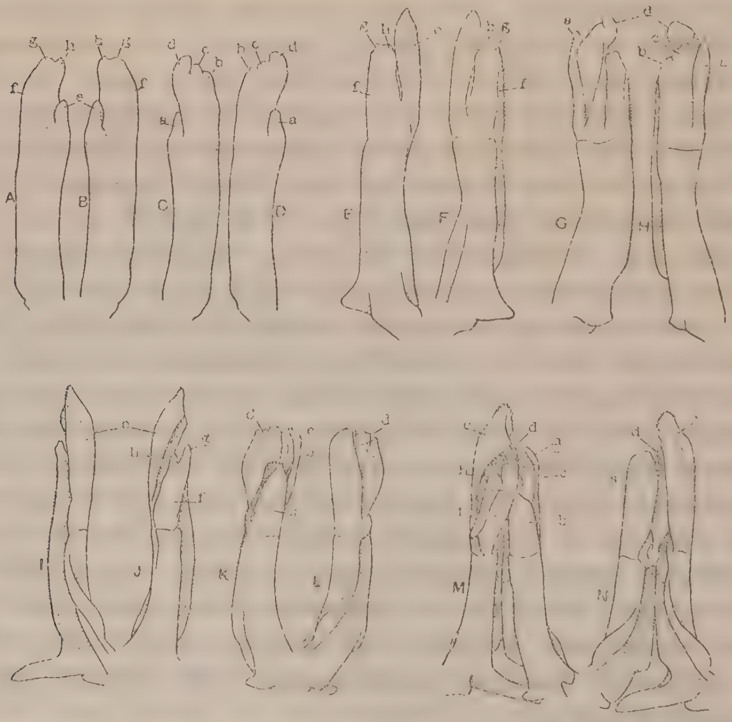

Fig. 42. Metamorphosis of petasma of *Metapenaeopsis barbatus*. *A, D, F, H, J, K,* and *M,* dorsal aspect; *B, C, E, G, I, L,* and *N,* ventral aspect, *a,* right disto-ventral projection. *b,* right disto-median lobule; *d,* disto-ventral flap; *e,* left disto-ventral projection; *f,* left disto-dorsal lobule; *g,* inner intermediate strip; *h,* outer intermediate strip. *A*-*D,* 19.5 mm in body-length, ×55; *E*-*H,* 30.5 mm in body-length (6.5 mm inc arapace-length), ×35; *I*-*L,* 44 (9.5), ×11; *M* and *N,* 51.5 (11.8), ×8.5.

inward, ogival in outline, as long as the proximal piace on which it lies, surpassing tip of the right disto-ventral projection, armed with eight short pointed setae along apical border. The left distodorsal lobule gets lamellar and subrectangular in outline, thrice as long as wide, half as long as the proximal piece of the left endopodite, considerably slenderer than that of the preceding stage, 30.5 mm long, and directed somewhat anteromedially. The inner intermediate strip is a remarkably lengthened laminar, somewhat narrow distally with rounded apex, one-third the length of the left disto-dorsal lobule. The outer intermediate strip is very similar in feature to the inner intermediate one, but half the length of the inner intermediate one (Fig. 42, *I* and *J*).

At the stage, 51.5 mm in body-length, the petasmal endopodite already coupled together with each other. Petasma measures about 4.8 mm and 1.1 mm in length and breadth respectively, differs in the following respects in comparision with that of the preceding stage, 44 mm long. The light disto-ventral projection is four-fifths the length of the proximal piece. The disto-median lobule is furnished with short fine setae on apical surface. The left distoventral projection bears about 9 spinules, some of which are bifid. The left disto-dorsal lobule is provided on outer surface with a longitudinal suture which splits into two diverging beanches near base. The inner and outer intermediate strips are remarkably widened, the former is about half the length of the left disto-dorsal lobule, and the latter much smaller than the inner intermediate strip (Fig. 42, *M* and *N*).

The petasma of an adult male (64 mm in body-length) measures ca. 7 mm in length, 1.8 mm in breadth (Fig. 18, *D* and *E*). The proportion of length to width becomes smaller than that of the stage, 51.5 mm long, decreasing from ca. 4.4 to 3.9. The distal elements undergo some changes in configuration, becoming as lohg as the proximal piece, rather abruptly narrowed into an apical appendage which is armed with three or four setae at apex. As regards the left disto-ventral projection, the relative length against the proximal piece is raised from ca. 1 to 1.3 during the animal grows from 51.5 mm to 64 mm in body-length, and most of the apical armatures get bifurcate. The inner intermediate strip appears much slenderer, ca. 0.8 times the length of the left disto-dorsal lobule, reaches somewhat beyond apex of the disto-median lobule and the distoventral flap. The outer intermediate strip is about half as long as the inner intermediate one, and ragged bearing fine setae at apex.

Metapenaeopsis acclivis. A young individual, 29 mm long, has the petasmal endododites still subequal (about 1.2 mm) in length, but already much asymmetrical in configuration of the protuberances set on the dorsal lobule of the lateral lobe and the appendages which form the distal pieces (Fig. 43, *A–D*). The median lobe is furnished with numerous cincinnuli along inner border. The dorsal lobule of the lateral lobe has an inwardly directed papilla-like protuberance. The disto-ventral projection is slender, pointed at apex, about two-thirds as long as the proximal piece of the endopodite. The right disto-dorsal lobule is simply lamellar, somewhat narrowed toward tip, rounded at apex, and extends to three-fourths of the right disto-ventral projection. The disto-median lobule is hardly defined yet. The disto-ventral flap is considerably elongated, membranous, ribbon-like, a little narrowed distally, twisted twice with rounded apex which is directed antero-laterally, and well exceeds tip of the right disto-ventral projection. With regard to the left endopodite, the proximal piece is intimately resembles that of the right endopodite except that the protuberance inserted on the basal median edge of the dorsal lobule of the lateral lobe is much larger than the other. The left distodorsal lobule is subrectangulr in outline, thrice as long as wide, a little less than half the length of the proximal piece of the endopodite. Both the inner and outer intermediate strips are hardly differentiated yet. The left disto-ventral projection is also lanceolate, about four times as long as wide measured at middle, somewhat shorter than the proximal piece of the endopodite, armed on apical border with about eight spinules, two or three of which are bifid (Fig. 43, *A* and *B*). The petasmal endopodites undergo a striking metamorphosis in feature of the appendages of the distal piece and the protuberances attached to posterior border of the dorsal lobule of the lateral lobe during the shrimp grows from 29 mm to to 41 mm in body-length. The right disto-ventral projection is concavo-convex as in *Meapenaeopsis barbatus*, three-quarters the length of the proximal piece of the endopodite, carries a small number of short setae on apical border. The right disto-dorsal lobule reaches to about middle of the right disto-ventral projection. The disto-median lobule compressed laterally, a little exceeded by the disto-ventral projection, furnished with closely set short setae on apical surface. The disto-ventral projection is much increased in length, well coiled sinistrally in distal half (Fig. 43, *G* and *H*). In the left endopodite, the protuberance, which stands on posteromedian border of the dorsal lobule of the lateral lobe, is remarkably slender, bluntly pointed at apex, directed slightly postero-medially, about half as long as the proximal piece of the endopodite. The left disto-ventral projection is spoon-shaped, convex on outer surface, subequal in length with the proximal piece of the endopodite, possesses about seven apical spinules, some of which are bifid. The left disto-dorsal lobule is subrectangular in outline thrice as long as wide, a little less than half the length of the proximal piece of the endopodite, and directed antero-medially. The inner intermediate strip rather slender, rounded at apex, directed forward, half as wide as the left disto-dorsal lobule, a trifle less than half the length of the left disto-dorsal lobule, provided with rather sparsely set fine setae on distal surfaces. The outer intermediate strip is very similar to the inner intermediate one in general feature but is about half of the latter in length (Fig. 43, *E* and *F*).

When the animal attains a length of 45.5 mm in body-length, the petasmal endopodites come into contact with each other. The apparatus measures a length of about 5 mm and a width of 1.2 mm (Fig. 43, *I* and *J*). The endopodites closely resemble those of the preceding stage, 41 mm long, in general feature, but differ from the latter in the following respects. The relative length of the protuberance inserted on the postero-median border of the dorsal lobule of the lateral lobe, and that of the left disto-ventral projection against the proximal piece of the apparatus are raised from 0.4 to 0.5 and from 1 to 1.4 respectively. The apical appendages of the left disto-ventral projection much developed, increase in number from about 7 to 11, most of which get bifurcate. The left disto-dorsal lobule furnished on dorsal surface with a longitudinal suture which splits into two diverging branches near base. The inner intermediate strip is two-thirds the length of the left disto-dorsal lobule, truncate on distal border which runs slightly antero-medially against the median axis of the petasma. The outer intermediate strip is half as long as the left disto-dorsal lobule, rounded at apex, distally ragged with rather closely set short pointed setae.

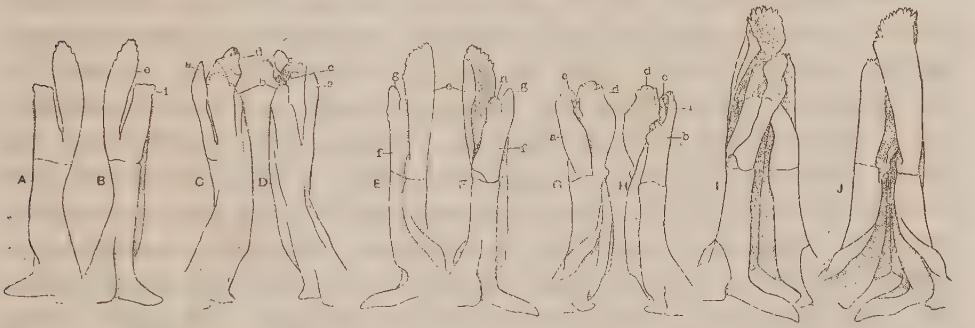

Fig. 43. Metamorphosis of petasma of *Metapenaeopsis acclivis* in three specimens measuring in body-length and carapace-length (put in brackets) in mm respectively as follows:—29 (6.9) (*A*-*D*); 41 (9.5) (*E*-*H*); and 45.5 (10.5) (*I* and *J*). *A, C, E, G,* and *J*, ventral aspects. *B, D, F, H,* and *I*, dorsal aspects. *A*-*D*, ×28; *E*-*H*, ×9.2; *I* and *J*, ×8.4. Other legends are the same as in Fig. 42.

The petasma of an adult form, 53.5 mm in body-length, measures about 11 mm in total length and 2.4 mm in width measured at the middle (Fig. 18, *A* and *B*), chiefly stands at variance with that of the stage, 45.5 mm long, in the following points. The right disto-ventral projection is as long as the proximal piece of the petasma, extends slightly beyond apex of the inner intermediate strip, the apical setae are much increased in size. The disto-ventral flap well surmounts apex of the outer intermediate strip. The left disto-ventral projection is one and half times the length of the proximal piece of the petasma; the apical appendages are remarkably increased in size, more or less fleshy, rather abruptly pointed at apex and curved to various directions. The inner intermediate strip is subequal in length to the left disto-dorsal lobule, the outer intermediate one a trifle less than three-fourths the length of the left dorsal lobule.

Metapenaeopsis dalei. A male measuring 39 mm in body-length has the petasma composed of the component endopodites already conjoined together with each other along the median border (Fig. 33, *A* and *B*). The petasma is about 4 mm and 1.4 mm in length and breadth respectively. The proximal piece measures ca. 1.8 mm. The protuberance set on the postero-median edge of the dorsal lobule of the right lateral lobe is small, narrowed distally, rounded at apex, and directed postero-medially. The right distoventral projection is foliaceous, strikingly expanded, irregular in outline, wavy on outer surface, and devoid of apical setae. The right disto-dorsal lobule reaches to the middle of the right distoventral projection. The disto-median lobule and the distoventral flap are hidden by the right disto-ventral projection and the right distoventral lobule, the latter extending to about two-thirds of the right distoventral projection, thin, ribbon-like and rolled sinistrally in distal half as in that of *Metapenaeopsis barbatus* and *M. acclivis.* The proximomedian protuberance of the dorsal lobule of the left endopodite is about half the length of the proximal piece of the petasma, thrice as long as wide, rather suddenly narrowed distally, rounded at apex, and directed postero-medially. The left disto-ventral projection is slender, somewhat longer than the proximal piece of the petasma, apically furnished with a small number of pointed spinules. The left dorsal piece is rather slender, directed somewhat anteromedially, and turns postero-laterally in subterminal portion with semicircularly rounded disto-median border.

In somewhat advanced stage, 45.5 mm in body-length, the organ undergoes some changes in general configuration comparing with that of the preceding stage, 39 mm long, in the following items: the petasma measures ca. 4.4 mm in length. The left disto-ventral projection has five ill-calcified spines, two of which are tipped with two conical spinules (Fig. 33, *C–H*).

The petasma of an adult male, 70 mm in body-length is 6 mm in lenghth, three times as long as wide measured at the middle, a little differs in feature from that of the preceding stage, 45.5 mm long. The left disto-ventral projection curves medially and overlaps apex of the right disto-ventral projection; the apical appendages are notably lengthened, two or three of which are bifid at tip (Fig. 33, *I* and *J*).

Metapenaeopsis coniger. In a juvenile specimen measuring a length of 48 mm, the petasma is about 4.3 mm in length, three and half times as long as wide (Fig. 35, *A* and *B*). The protuberance attached to the proximal inner rim of the dorsal lobule of the right lateral lobe is rather sharply pointed, directed a little postero-medially extending somewhat beyond the median axis of the petasma. The right disto-ventral projection is near in configuration to that of similar-sized specimens of *Metapenaeopsis barbatus* and *M. acclivis,* and carries several spinules at apex. The disto-median lobule has rather closely set acute fine setae on apical surface. The disto-ventral flap is thin and rolled as in *M. barbatus M. acclivis* and *M. dalei.* The protuberance raised from postero-median fringe of the dorsal lobule of the left lateral lobe is half as wide as long, two-fifths the length of the proximal piece of the petasma, accuminate at tip, directed postero-medially, and overlaps apex of the opposite fellow. The left disto-ventral projection is as long as the proximal piece of the petasma, much broader and longer than the right disto-ventral projection, smooth on outer surface, devoid of spinules on apical border. The left disto-dorsal lobule is rather slender, 0.8 times the length of the proximal piece of the petasma, directed antero-medially, rounded at apex, two-ninths as long as wide, and furnished on outer surface with a somewhat wavy suture which branches into two near base as in *M. barbatus* and *M. acclivis.*

At the time the animal measures 58 mm in body-length, the pstasma is about 5.8 mm in length, and 1.8 mm in breadth (Fig. 35, *C–F*). The petasma closely resembles that of the preceding stage, 48 mm in body-length, in general aspect, but differs from the latter in the points given in the following lines. The right disto-ventral projection is almost equal in length with the proximal piece of the petasma, armed with 4 or 5 short spinules on apical edge. The left disto-ventral projection extends as far as the right disto-ventral projection, carries on apical border about 8 pointed spinules which are different in size.

As shown in Fig. 35, *G* and *H*, the petasma of an adult male, 65.5 mm long, displays little modification in general aspect compared with that of the stage, 58 mm long except that the distal piece is about 1.4 times the length of the proximal piece instead of being as long as the latter.

Remarks: The asymmetry of the petasma already appears slightly, and the articulation laid down between the proximal and distal pieces of the petasma is defined very weakly in such young form of *Metapenaeopsis barbatus* as 19.5 mm in body-length. The petasmal asymmetry becomes gradually emphasized in degree, and the articulation gets clearer with advance of age. Therefore, so far as present investigation goes, it follows without doubt that the unequality and the segmented condition of the asymmetrical petasma are positive features of specialization. The median lobe is not found markedly developed in *M. barbatus* when the animal measures 19.5 mm in body-length. But the lobe is well differentiated already at the stage, 29 mm long in *M. acclivis* and 30.5 mm long in *M. barbatus* as a narrow lobe extending near base of the petasmal endopodite to about inner base of the right or left disto-dorsal lobule. It follows, therefore, that all the distal elements of the asymmetrical petasma are originated from the lateral lobe as is the case with the apical projections of *Metapenaeus affinis*, *M. joyneri*, *M. monoceros*, *Trachypenaeus curvirostris*, *Atypopenaeus compressipes*, and *Parapenaeopsis tenellus*. The mode of the channel formation appears to be essentially equal to that of *Metapenaeus affinis*, *M. monoceros*, *M. joyneri*, and *Trachypenaeus curvirostris*. In an early stage, 19.5 mm long, each petasmal endopodite of *M. barbatus* is considerably thickened on outer side. The ventral surface of the thickened portion grows a longitudinal ridge. The longitudinal ridge undergoes a rapid development yielding a rather thickened wall directed ventro-medially, and goes to form the lateral wall of the channel as the growth continues. The wall is found rather developed in the stage, 30.5 mm long, in *M. barbatus* and in the stage, 29 mm long in *M. barbatus*, and the wall almost complete in feature somewhat earlier than the endopodites coming into contact with each other.

In the stage, 19.5 mm long, of *M. barbatus* the distal piece of the right petasmal endopodite is made up of two, inner large and outer small, lobes as set forth already. The large lobe has three rudiments with rounded apex along the distal border, of which the proximal rudiment corresponds to the disto-dorsal lobule, the intermediate to the disto-median lobule, and the distal to the disto-ventral flap. The small lobe is the rudiment of the right disto-ventral projection. Among the four elements, the right disto-ventral projection and disto-ventral flap undergo merked displacement, shifting gradually ventrally with age. So that, the disto-dorsal lobule is located on distal border of the dorsal lobule of the lateral lobe, the disto-ventral projection on the distal outer rim of the ventral lobule of the lateral lobe, the disto-ventral flap on the distal inner rim of the ventral lobule of the lateral, and the disto-median lobule is embraced by the distodorsal lobule, disto-ventral projection, and disto-ventral flap arising from outer base of the disto-ventral projection. Moreover, the left disto-ventral projection also undergoes similar displacement as in the right disto-ventral projection. Such transitional condition of the petasmal endopodite is observed in the stage, measuring 30.5 mm long, in *M. barbatus*, and 29 mm long, in *M. acclivis*. In passing, both the right and left disto-ventral projections of

M. barbatus and *M. acclivis* rapidly lengthen in the stage, about 30 mm in body-length. The growth of the projection in question is much faster than that of all other elements forming the distal piece, especially that of the left disto-ventral projection is positively heterogonic against that of the proximal piece. The apical armatures of the right and left disto-ventral projection of *M. barbatus* and *M. acclivis* occur much later than those of *M. acclivis*. They are found to exist at the stage, about 60 mm long, in the first two species, and at the stage, about 40 mm long, in the third. On the other hand, the armatures of the left disto-ventral projection are found considerably developed already in even the stage, 29 mm long, in *M. acclivis*, whilst those are still single in number in the stage, 30.5 mm long, in *M. barbatus*, absent in the stage, 48 mm long, in *M. coniger*. It is worth mentioning that the petasma is found already united in the stage, 51.5 mm long in *M. barbatus*, 45.5 mm long, in *M. acclivis*, 48 mm long in *M. coniger*, and 39 mm long in *M. dalei*.

e. Phylogenetical and systematic considerations of petasma.

General configuration of petasma shows remarkable variation throughout all the species dealt with, but is species-specific in most cases. As regard the configuration, the petasma is divisible into eleven super-specific and supergeneric types, M_1–M_{11}, as mentioned elsewhere. However, the types are again diviaible into two, one of which is characterized by being symmetrical and not segemented, and the other by being asymmetrical and segmented into two: proximal and distal pieces. The former division is represented by Types, M_1–M_{10}.

The ten symmetrical types may be also classified into three groups taking the cross-section of petasma into consideration. The first group consists of five types, M_1–M_5, in which the cross-section is of types–PC_1 or PC_2. The second involves Types, M_6 and *Trachypenaeus*–type (Type–M_{10}) with cross-section Type–PC_3. The third embraces Types–M_7–M_9, characterized by the cross-section, Type–PC_4.

The Type–M_1 may be taken as the most primitive among the eleven Types, by the following many primitive characters: the petasmal endopodites are membranous, not conjointed with each other along median border, not folded longitudinally, and devoid of cincinnuli; median and lateral lobes as well as dorsal and ventral lobules not differentiated; and any appendage other than two apical strips is absent. The Type–M_2 is the nearest to the Type–M_1 in general aspect, but more specialized than the latter in the following items: each of the endopodite is folded longitudinally, and has many cincinnuli along median edge; and the component lobes and lobules are well defined. The Types, M_3 and M_4, which intimately resemble each other, are allied to the Type–M_1 in palingenetic relation as mentioned already, more specialized than the Type–M_2 by having deep channel. The Type–M_5 is the most specialized among the types referable to the first group which is marked by the cross-section Types, PC_1 and PC_2, possession of numerous pointed setae along distal lateral margins of the lateral lobes and processes, *a* and *b*.

The second group includes Type–M_6 and *Trachypenaeus*–Type (which belongs to Type–M_{10}). The Type–M_6 shows striking speciality in apical portion which is thickened, overlapping subterminal ventral edge of the lateral lobe and provided with many ragged lobules and spines–*a–d*, and in having sping–*e*. But the general feature is very similar to that of Types–M_3 and M_4. Moreover, this type appears to be linked with Type–M_7 in the annexed respects: the spine–*e* and the diagnostic apical appedage of the Type–M_6 are perhaps homologous with triangular process attached on dorsolateral border near proximal end of the median lobe and the thickened apical portion of the median lobe of the Type–M_7 respectively. The *Trachypenaeus*-type is of course most closely related to the typical form of the Type–M_{10}, besides that it demonstrates intimate affinity with the Type–M_8, since the wing-like disto-lateral projections and the protuberances inserted on postero-median border of dorsal lobule of lateral lobe of *Trachypenaeus*-type are, as set forth already, homologous with the apical outer projections and the protuberances lying on postero-median edge of dorsal lobule of lateral lobe of the Type–M_8 respectively.

The four types, M_7–M_{10} (except *Trachypenaeus*-type), which are ascribable to the third group, seem to be closely related to one another by having disto-lateral projections, besides that they are each firmly linked with Type–PC_4 in cross-section. In the Type–M_9, the petasma is furnished at disto-lateral angle with dorsal and ventral spiniform projections which are not fused along outer margins, but the former is raised from the dorsal lobule of the lateral lobe and the latter from the ventral lobule of the same lobe as is the case with Types, M_7, M_8 and M_{10}. Perhaps this condition is a primitive feature of the short trough-like distolateral projections of Types, M_7, M_8 and M_{10}. Again the apical inner spine of the Type–M_9 is probably homologous with the apical inner projection of the Type–M_8. Therefore, the Type–M_9 is nearer to the Type–M_8 than to Types, M_7 and M_{10}. It should be remembered herewith that the Type–M_8 metamorphoses from a feature closely resembling the Type–M_1 as is the case with the Types, M_2 and M_3.

The asymmetrical type, M_{11}, is greatly deviated from the symmetrical ones in many important respects. But the distal piece of both the petasmal endopodites is composed of two inner larger and outer smaller lobes as stated already. It appears to the writer that the two lobes correspond to the two apical projections of the Type–M_8. Should this conception be true, Type–M_{11} also may be regarded as given rise to from an hypothetical ancestor like Type-M_1.

Conclusively, it may be considered that the Types, M_1–M_{11}, were diverged from the same phylogenetical source which is similar to the Type-M_1.

The synoptical key given below to the Types of petasma and to the species is made to indicate the phyletic relationship also intended to be of practical use.

A_1 Both petasmal endopodites are symmetrical, unsegmented; cross-section is of Types, PC_1-PC_4.

  B_1 Cross-section is of Types, PC_1-PC_3 (petasma is widely or rather widely opened on ventral side).

    C_1 Petasma depressed, cross-section belongs to Type-PC_1.

      D_1 Longitudinal folds not defined, median and lateral lobes not differentiated, cincinnuli absent, anterior margin of each endopodite carries two lobulettes, right and left endopodites are not linked together with one another ....Type-M_1 *Miyadiella pedunculata.*

      D_2 Longitudinal foldings are defined, both median and lateral lobes well defined, numerous cincinnuli present along median border, both endopodite combined or not, distolateral and lateral margins provided with one-two processes or none ....Type-M_2.

        E_1 Each petasmal appendage without prominent appendage ....*Aristaeus virilis.*

        E_2 Each petasmal appendage furnished with a prominent appendage on disto-lateral or lateral border.

          F_1 Prominent appendage of petasmal endopodite truncate at apex, and directed anteriorly; dorsal lobule of lateral lobe has no process on posterior border.

            G_1 Median lobe with a slender strip on distal border; a prominent appendage situated on disto-lateral border, about twice as long as wide ....*Parahaliporus sibogae.*

            G_2 Median lobe without strip on distal edge; a prominent appendage located near middle of lateral border, about five times as long as wide ....*Aristaeomorpha foliacea.*

          F_2 Prominent appendage of petasmal endopodite sharply pointed at tip, and directed antero-medially; posterior border of dorsal lobule of lateral lobe has a horn-like process directed postero-medially ....*Penaeopsis rectactus.*

    C_2 Cross-section is of Type-PC_2 (petasma rather compressed, main channel deep)

      H_1 Disto-lateral margin is not furnished with numerous setae, median lobes posterior-ly tubular, and considerably surmount basal border of lateral lobe; lateral lobe without large spatulate process on ventral free margin.

        I_1 Ventral free margin of lateral lobe well calcified, thickened, acutely pointed at tip, and semicircularly recurves dorally in distal portion which is armed with a number of minute but stout spinules ....Type-M_3.

          J_1 Protuberances found at apex of median lobes extend well beyond distal margin of lateral lobe

            K_1 Protuberances set on distal border of median lobes curve ventrally somewhat overlapping distal margin of lateral lobe ....*Penaeus japonicus, P. latisulcatus, P. monodon,* and *P. brevirostris.*

K_2 Protuberances present at apex of median lobes do not bend ventrally ....*Penaeus orientalis.*

J_2 Protuberances located at apex of median lobes stretch as far as or do not reach to distal margin of lateral lobe ....*Penaeus barbatus, P. longistylus, P. teraoi, P. indicus, P. penicillatus, P. merguiensis,* and *P. esculentus.*

I_2 Free margin of lateral lobe thin, membranous, not sharply pointed at apex, and not semicircularly recurves dorsally in apical portion which is destitute of spinules ....Type-M_4.

L_1 Median lobe bluntly pointed at tip, and reaches to apex of lateral lobe ....*Penaeus stylirostris.*

L_2 Median lobe truncate on distal border, and remarkably surmounts tip of lateral lobe ....*Penaeus vannamei.*

H_2 Disto-lateral margin of lateral lobe fringed with rather closely set numerous setae; posterior margin of median lobe extends posteriorly as far as posterior edge of lateral lobe; ventral free border of lateral lobe usually provided with a large spatulate projection which is armed with many setae on apical border ....Type M_5.

M_1 Apex of median lobe considerably or strikingly exceeds tip of lateral lebe

N_1 A lobulette (process-*b*) present on dorsal surface of each lateral lobe at about three-fourths

O_1 Setae lying along each disto-lateral margin of lateral lobe relatively larger in size, range from 45 to 50 in total number; lobulette laid down on dorsal surface of lateral lobe fringed with more than ten setae ....*Solenocera pectinulata.*

O_2 Setae supported along each lateral edge of lateral lobe relatively smaller, vary from 55 fo 66 in total number; lobulette attached to dorsal surface of lateral lobe furnished with several setae. ....*Sloenocera faxoni.*

N_2 Lobulette (process-*b*) absent on dorsal surface of lateral lobe

P_1 Apical projection of dorsal lobule of lateral lobe semicircularly rounded on distal border which is armed with a large number of rather long pointed setae ....*Solenocera brevipes.*

P_2 Apical projection of dorsal lobule of lateral lobe pointed or irreglar on distal border which is provided with a large number of compactly set and sharply pointed setae (these setae are sometimes not defined in adult form)

Q_1 Apical projection of dorsal lobule of lateral lobe rather acutely pointed, about one fourth as long as entire petasma; setae set on distal outer border of the apical projection not defined in adult form, but well defined and fine in young form.........*Hymenopenaeus lucasii.*

Q_2 Apical projection of dorsal lobule of lateral lobe irregular on distal border; setae set along outer margin compact, sharply pointed ....*Hymenopenaeus aequalis.*

M_2 Apex of median lobe hardly reaches to, or slightly surpasses, tip of lateral lobe

R_1 Median lobe slightly surmounts tip of lateral lobe; setae set along distal border of dorsal lobule of lateral lobe and those set along disto-lateral border of ventral lobule of lateral lobe are somewhat vestigial, setae set along distal border of dorsal lobule of lateral lobe vary from 26 to 28 in number and those set on distolateral border of ventral lobule of lateral lobe 18–20 in number; spatulate process arising from each ventral free border of lateral lobe without setae on distal edge ....*Solenocera subnuda.*

R_2 Median lobe hardly reaches to distal margin of lateral lobe; setae set on disto-lateral border of lateral lobe conspicuous; spatulate process provided with 12–16 short pointed setae on apical border

S_1 Disto-lateral margin of dorsal lobule of lateral lobe carries 12–15 setae, but that of ventral lobule of lateral lobe is bare; ventral lobule of lateral lobe has a spine directed forward at about middle of dorsal surface *Solenocera prominentis.*

S_2 Distal margin of dorsal lobule of lateral lobe armed with about 18 setae, and that of ventral lobule of lateral lobe with about 16 setae; ventral lobule of lateral lobe without spine on dorsal surface ....*Solenocera depressa.*

C_3 Petasma rather depressed; cross-section belongs to Type-PC_3; terminal portion without a pair of large wings or horns, but is markedly thickened, fleshy, provided with ragged petaloid lobules, of which ventral ones somewhat extend backward and overlap distal about one-fourth of ventral free margins of lateral lobes, armed with well calcified spines (spines *a*–*d*); median lobes dorsally carry a pair of subrectangular rigid processes near basal border ....Type-M_6

T_1 Spine–*a* bifurcate at apex

U_1 Apical spinules subequal in size; spine-*b* acutely pointed, spine-*d* prominent *Parapenaeus fissurus.*

U_2 Apical spinules different in size (anterior one much smaller); spine-*b* bluntly pointed; spine–*d* absent ....*Parapenaeus sextuberculatus.*

T_2 Spine–*a* simply pointed

V_1 Spine–*a* prominent, acutely pointed, directed slightly upward; spine-*b* salient, acute at tip, directed considerably upward; spine–*d* rather rudimentary; spine-*e* rather broad, about as wide as long ....*Parapenaeus lanceolatus.*

V_2 Spine–*a* small in size, bluntly pointed at apex, directed upward; spine–*b* truncate at apex, directed antero-dorsally, considerably thin, about half as wide as long *Parapenaeus investigatoris.*

B_2 Petasma rather strongly depressed except that of *Trachypenaeus,* in which it is rather compressed; cross-section is of Type-PC_4 (or Type-PC_3 in *Trachypenaeus* only); gap lying between both ventral free margins of lateral lobe is very narrow.

W_1 Lateral lobe has a large auriculate basal outgrowth which is depressed, rounded on outer margin, and directed sidewise; dorsal lobule of lateral lobe is provided with a prominent triangular process directed outward near base; disto-dorsal projection short, directed laterally, less than one-eighth the length of petasma ....Type-M_7.

X_1 Petasma about 2.5 times as long as wide measured at anterior base of the proximal auriculate projectons: disto-dorsal border smooth ....*Parapenaeopsis hardwickii,*

X_2 Petasma about twice as long as wide measured at anterior base of the proximal auriculate projections; disto-dorsal border serrated with several teeth *Parapenaeopsis cultrirostris.*

W_2 Lateral lobe without outstanding basal auriculate outgrowth, dorsal lobule of lateral lobe unarmed with a triangular process near base; disto-lateral projection short or long.

Y_1 Petasma less than thrice as long as wide measured at about middle; disto-median projection of dorsal lobule of lateral lobe small, pointed or truncate at apex, smaller than or subequal in disto-lateral one.........Type-M_8.

Z_1 Lateral margins of petasma without processes; disto-median processes smaller than disto-lateral ones

a_1 Disto-median processes truncate at apex; disto-lateral ones bluntly pointed at apex, the process of ventral lobule of lateral lobe has straight outer border which lies slightly antero-laterally ....*Eusicyonia cristata.*

a$_2$ Both disto-median and disto-lateral processes sharply pointed at tip; disto-lateral process of ventral lobule of lateral lobe abruptly recurves backward, and has a semicircular anterior border ....*Eusicyonia lancifer japonica.*

Z$_2$ Lateral margins of petasma armed with a pair of large sharply pointed spines; disto-median processes slightly convex on distal border, and as large as disto-lateral ones which are acuminate at apex ....*Eusicyonia curvirostris.*

Y$_2$ Petasma more than thrice as long as wide measured at about midway; disto-median projection of dorsal lobule of lateral lobe greatly larger than disto-lateral one, and hood-like or narrow plate-like ....Type-M_9.

b$_1$ Distomedian projection hood-like

c$_1$ Disto-median projection rectangular in outline, with free margins sidewise; disto-lateral projection rounded at apex, directed laterally ....*Metapenaeus affinis.*

c$_2$ Disto-median projection triangular in outline; disto-lateral ones acutely pointed at apex, dierected anterolaterally

d$_1$ Disto-median projection extending much beyond tip of disto-lateral projection, about 1.2 times as long as wide measured at base, with free margins dorsally, fringed with short pointed setae along distal about one-third of the outer lip ....*Metapenaeus monoceros.*

d$_2$ Disto-median projection reaching as far as tip of disto-lateral projection, about as long as wide measured along proximal border, with free margins sidewise, unarmed with setae along free edges ....*Metapenaeus intermedius.*

b$_2$ Disto-median projection narrow, plate-like, pointed at apex, channeled on ventral surface, and recurves dorsally and posteriorly in distal about half

e$_1$ Disto-median projection narrower; disto-lateral one about one-fourth the length of petasma except projections ....*Metapenaeus joyneri.*

e$_2$ Disto-median projection wider, disto-lateral one about one-fifth as long as main part of petasm ....*Metapenaeus tenuipes.*

Y$_3$ Disto-median projection absent; disto-lateral projection outstandingly developed, and wing-like or horn-like ....Type-M_{10}.

f$_1$ Cross-section belongs to Type-PC_3
disto-lateral projection elongated, triangular in outline, directed outward, and measuring about two-fifths the length of petasma ....*Trachypenaeus asper ; T. curvirostris.*

f$_2$ Cross-section is of Type-PC_{4b}

g$_1$ Disto-lateral projections very slender, directed laterally or antero-laterally

h$_1$ Petasma strongly depressed; disto-lateral projections acutely pointed at tip, directed laterally, and about two-fifths as long as petasma; ridge-*b* remarkably expanded outward, and sharp on apical border ....*Parapenaeopsis tenellus.*

h$_2$ Petasma rather depressed; disto-lateral projections gradually decrease in width toward distal end, truncate at apex, directed antero-laterally in distal one-third; about half the length of petasma; ridge-*b* thick, rounded on apical border ....*Parapenaeopsis cornutus.*

g$_2$ Disto-lateral projections large and thick, directed anteriorly

i_1 Disto-lateral projections subrectangular in outline, provided on dorsal surface with a narrow straight gap running somewhat antero-laterally, about three-fourths as long as main part of petasma; inner and outer lobes of disto-lateral projections obliquely overlap with each other in subterminal portion; inner lobe pointed at tip, directed antero-medially ....*Parapenaeopsis hungerfordi.*

i_2 Disto-lateral projections triangular in outline, acute at apex, armed with two or three apical spinules, about one-fifth as long as main part of petasma ....*Atypopenaeus compressipes.*

A_2 Both petasmal endopodites asymmetrical and two-jointed; cross-section is of Type-PC_5 ....Type-M_{11}.

j_1 Both right and left disto-ventral projections furnished with small pointed spines on apical border; distal piece of right petasmal endopodite smaller than that of left petasmal endopodite; disto-ventral flap extends as far as tip of right disto-ventral projection, and as large as right disto-ventral projection.

k_1 Left disto-ventral projection much longer than right disto-ventral one, and has large apical spines

l_1 Apical spines of left disto-ventral projection less than one-ninth the length of left disto-ventral projection; both inner and outer intermediate strips defined, inner one greatly exceeded by left disto-ventral projection

m_1 Inner intermediate strip subrhombic in outline, much larger than outer intermediate strip, and extends beyond apex of outer intermediate one

n_1 Left disto-ventral projection provided on apical border with about 16 veriously directed conical spinules, some of which are bifurcate at apex; right disto-ventral projection has about 7 apical spinules ....*Metapenaeopsis acclivis.*

n_2 left disto-ventral projection furnished on apical edge with about 7 pointed spinules directed anteriorly, most of the spinules are bifid; right diato-ventral projection bears 3 or 4 acute spinules at apex ....*Metapenaeopsis barbatus.*

m_2 Inner intermediate strip slender, bar-shaped, bluntly pointed at apex in dorsal aspect, much smaller than and much exceeded by, outer intermediate strip; left disto-ventral projection provided along apical border with about 15 pointed spinules directed anteriorly or somewhat anterolaterally, some of the spinules bifid at apex ....*Metapenaeopsis durus.*

l_2 Apical spines of left disto-ventral projection about one-third as long as the projection in question, two in number, different in size; apex of right disto-ventral projection has a spine which is as large as larger apical spine of left disto-ventral projection; left dorsal piece reaches as far as apex of disto-ventral projection; both inner and outer intermediate strips not defined ....*Metapenaeopsis lamellatus.*

k_2 Left disto-ventral projection and right disto-ventral one subequal in length, and has minute apical spines; both inner and outer intermediate strips not defined ....*Metapenaeopsis coniger.*

j_2 Apical spines set on distal border of left disto-ventral projection only; distal piece of right petasmal endopodite much larger than that of left petasmal endopodite; disto-ventral flap does not reach to apex of right disto-ventral projection, and much smaller than the same projection; left disto-ventral projection provided on distal border with several long, spiniform strips which overlap apex of right disto-

ventral projection; both inner and outer intermediate strips not defined
.........*Metapenaeopsis dalei.*

K. THELYCUM

a. General feature.

The thelycum consists of a series of prominences, depressions or grooves, plates and sacs raised from sternites of the sixth to eighth thoracic segments. This organ affords, just as the petasma, a clue significant for the descrimination of species of Penaeids. BATE (1888), KISHINOUYE (1900), RATHBUN (1902), BALSS (1914), and PARISI (1919), especially KISHINOUYE, have done valuable contributions on this apparatus of Japanes species of this family. But our knowledge of the organ is still incomplete in many respects. Hence comparative investigation was tried by the present author as accurate as possible, with the following results.

The thelycum is considerably variable in general features in the species dealt with. It falls, however, within certain ranges, viz., species-specific in most cases, and referable to eight superspecific types, which are called herein Types, N_1–N_8.

Type–N_1: This type is the simplest in general aspect as shown in Fig. 44. The six species of *Solenocera* belong to this type. Both sternites of seventh and eighth thoracic segments are provided with hardly developed upheavals and ridges or devoid of such elements. Between, and a little behind, fourth pereiopods a rather vestigial triangular plate with emarginate apex directed obliquely forwards is given rise to from posterior margin of penult thoracic sternite in *S. prominentis* and *S. depressa*, a conical elevation in *S. subnuda*, and an emarginate shelf in *S. brevipes*. The last thoracic sternite of *S. prominentis*, *S. subnuda*, and *S. depressa* carries a quadrate area bounded by row ridges; the area of *S. depressa* has an upstanding conical elevation at center. The same sternite of *S. brevipes* and *S. alticarinata* is provided with a transverse swelling at middle. The sewelling of *S. brevipes* is posteriorly trilobate with rounded apices, and that of *S. alticarinata* rather narrow, and somewhat saddle-shaped. Moreover, the sternite in question of *S. prominentis* gives off a deltoid elevation which is concave at apex, directed somewhat antero-ventrally, similar to but much larger than that lying on sternite between and a little behined fourth pereiopods.

Type–N_2: Median plate set on sternite between fourth pereiopods present or absent. If present, it is concavo-convex with concave surface backward, directed slightly antero-ventrally. Sternite of the last thoracic segment upheaved as a conspicuous pyramidal elevation with two surfaces posteriorly, or provided with a pair of upstanding rather thin transverse walls directed antero-laterally at about middle, and has unelevated posterior edge (Fig. 47, *U* and *V*).

Two Pacific American species, *Penaeus stylirostis* and *P. vannamei*, are included in this type. It should be noticed that each fourth pereio-

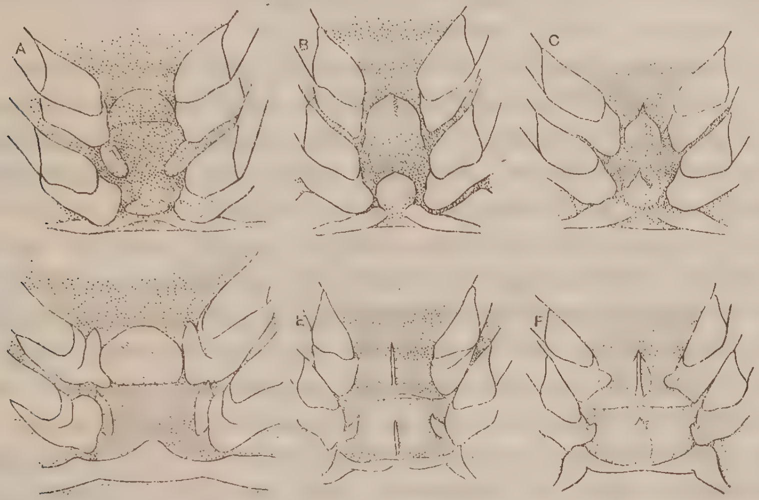

Fig. 44. Thelycum of *Aristaeomorpha foliacea* (*A–C*), *Aristaeus virilis* (*D*), and *Parahaliporus sibogae* (*E* and *F*). *A*, 130 mm in body-length (44.3 mm in carapace-length), ×3; *B*, 65 (22), ×7.5; *C*, 60 (18), ×8; *D*, 110 (34), ×3.5; *E*, 115 (30), ×2; *F*, 71 (19), ×4.

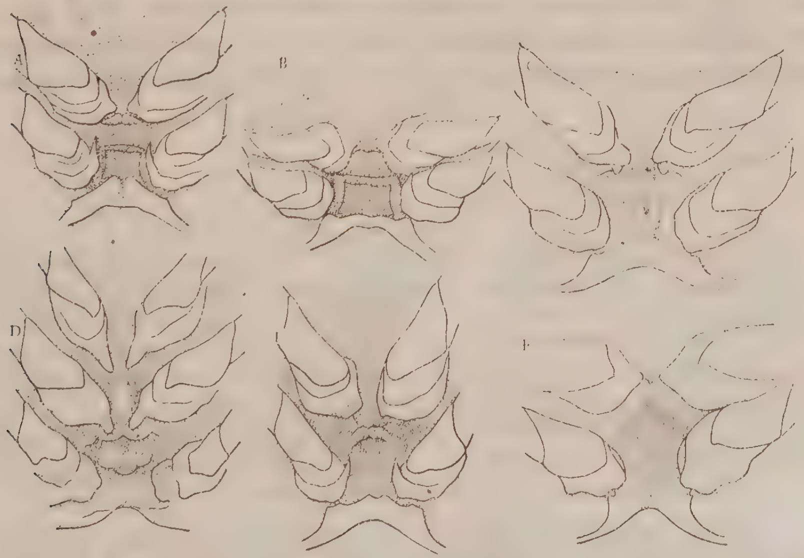

Fig. 45. Thelycum of Type-N_3. *A*, *Solenocera prominentis*, 105 mm in body-length (33 mm in carapace-length) ×2; *B*, *Solenocera subnuda*, 56 (17.5); *C*, *Solenocera depressa*, 80 (26), ×3.5; *D*, *Solenocera brevipes*, 54.2 (16.6), ×3.5; *E*, *Solenocera alticarinata*, 95 (22), ×6; *F*, *Solenocera faxoni*, 50 (16.5), ×6.

pod is furnished with a strikingly developed spatulate coxal plate.

Type–N_3: A well developed ridge or plate present on sternite between fourth pereiopods, and a ridge on sternite between fifth pereiopods or a rather vestigial plate at middle of posterior edge of the last thoracic sternite. A pair of compressed spinous projections present or absent at middle of the last thoracic sternite.

Aristaeomorpha foliacea, *Aristaeus virilis*, and *Parahaliporus sibogae* belong to this type. The median projection lying on sternite between the fourth pereiopods is transversely broad, raised antero-ventrally in *Aristaeomorpha foliacea* and *Aristaeus virilis*, narrow, directed anteriorly with pointed apex in *P. sibogae*. The last thoracic sternite is flattish, armed with a pair of spinous projections at middle and an upstanding pointed median plate on the posterior border in *Aristaeomorpha foliacea*, provided with an inconspicuous inverted Y-shaped swelling at middle and a rounded boss at apex on the posterior edge in *Aristaeus virilis*, and somewhat convex and no appendage on the posterior rim in *P. sibogae*.

Type–N_4: A transverse plate lies on sternite between fourth pereiopods; the plate is wider than long, usually directed antero-ventrally, with a minute apical spine. A transverse ridge or rather narrow plate is present on sternite between the transverse plate laid down between fourth thoracic pereiopods and posterior edge of the last thoracic sternite; this ridge or plate curves anteriorly at each lateral end or has a projection directed forward at each outer end. Median process set on posterior margin of the last thoracic sternite is present or absent (Fig. 46).

All species of *Metapenaeopsis* belong to this type. The plate lying on sternite between fourth pereiopods is raised antero-ventrally and has

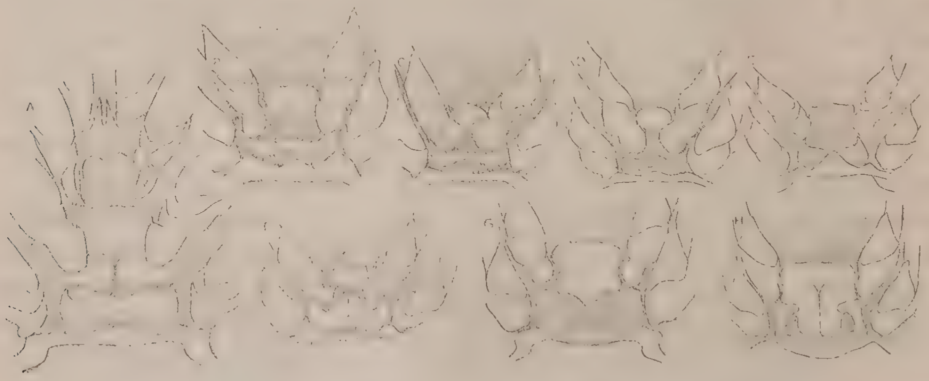

Fig. 46. Thelycum of Type-N_4. *A*, *Metapenaeopsis incomptus*, 70 mm in body-length (19 mm in carapace-length), ×4.8; *B*, *Metapenaeopsis barbatus*, 88 (21.5), ×3.2; *C*, *Metapenaeopsis acclivis*, 74.5 (17), ×2.8; *D*, *Metapenaeopsis durus*, 87 (20.1), ×2.4; *E*, *Metapenaeopsis dalei*, 72 (19.5), ×2; *F*, *Metapenaeopsis lamellatus*, 68.5 (17), ×1.6; *G*, *Metapenaeopsis latus*, 66 (15.2), ×4.8; *H*, *Metapenaeopsis coniger*, 62 (14), ×4.8.

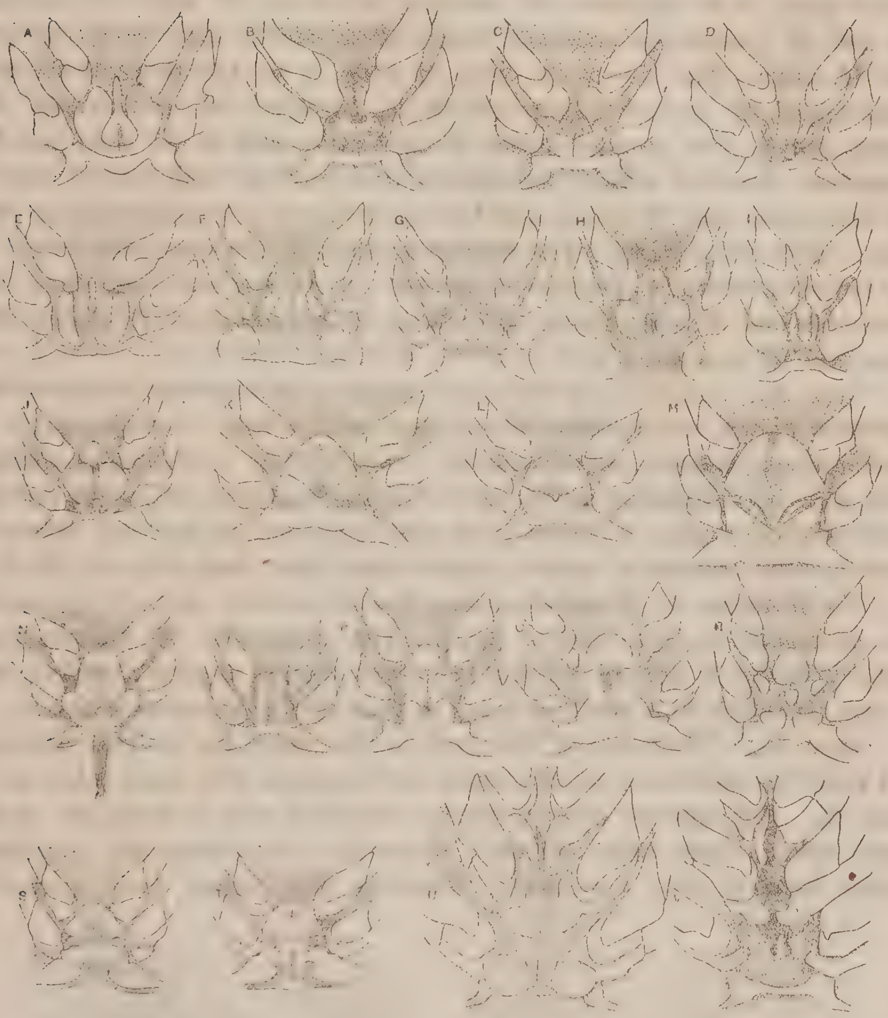

Fig. 47. Thelycum of Type-N_2 (*U* and *V*), Type-N_5 (*K*-*T*), and Type-N_7 (*A*-*J*). *A*, *Metapenaeus joyneri*, 115 mm in body-length (32 mm in carapace-length), ×2; *B*, *Metapenaeus monoceros*, 133 (11.7), ×2.8; *C*, *Metapenaeus affinis*, 83 (20), ×2.8: *D*, *Metapenaeus intermedius*, (27.5), ×4.8; *E*, *Trachypenaeopsis richtersii*, 43 (11.5), ×6; *F*, *Metapenaeus brevicornis*, 97 (27), ×2.4; *G*, *Metapenaeus spinulatus*, 94 (24), ×2.4; *H*, *Metapenaeus lysianassa*, 67 (16), ×2.6; *I*, *Atypopenaeus compressipes*, 43 (15), ×4.8; *J*, *Penaeopsis rectactus*, 198 (26), ×2.4; *K*, *Trachypenaeus curvirostris*, 72 (21), ×3.2; *L*, *Trachypenaeus asper*, 68 (19.5), ×2.2; *M*, *Parapenaeopsis tenellus*, 57 (17), ×4.8; *N*, *Parapenaeopsis cornutus*, 72 (20), ×2.8; *O*, *Parapenaeopsis hungerfordi*, 71 (20), ×2.4; *P*, *Parapenaeus fissurus*, 91 (26), ×2; *Q*, *Parapenaeus investigatoris*, (18.4), ×2.4; *R*, *Parapenaeus sextuberculatus*, 88 (24), ×2.4; *S*, *Parapenaeopsis hardwickii*, 87 (28), ×2; *T*, *Parapenaeopsis sculptilis*, 117 (40), ×1.6; *U*, *Penaeus stylirostris*, ×1.6; *V*, *Penaeus vannamei*, 155 (42), ×1.6.

apical spine in *M. barbatus*, *M. acclivis*, *M. dulus*, *M. dalei*, *M. incomptus* and *M. lamellatus*, embossed and without apical spine in *M. coniger* and *M. latus*. The transverse ridge or plate of the last thoracic sternite turns anteriorly at each lateral end in *M. barbatus*, *M. acclivis* and *M. durus*, armed with an acute spine at each outer end in *M. dalei* and *M. incomptus*, provided with a rectangular projection at each lateral end in *M. lamellatus* and *M. latus*, and has an inverted L-shaped ridge at the same end in *M. coniger*. The median process of the posterior edge of the hindmost thoracic sternite is present in *M. barbatus*, *M. dalei*, *M. incomptus* and *M. lamellatus*, and absent in *M. acclivis*, *M. dulus*, *M. latus* and *M. coniger*.

Type–N_5: Thelycum of this type consists of two anterior and posterior embossed plates, which come into contact with other. Anterior plate is semicircular, rhombic, subrectangular, triangular or cardiform in outline, with apex not extending much beyond anterior margin of fourth pereiopods. Posterior plate is raised from posterior edge of the last thoracic sternite, bifid anteriorly, usually much wider than long (Fig. 47, *K–T*).

The penaeids of *Trachypenaeus*, *Parapenaeopsis* and *Parapenaeus* are embraced in the present type. The apparatus of *Parapenaeus sextuberculatus* is greatly deviated from typical form in general aspect, but it may be taken as a modified form of that of *Parapenaeus fissurus*.

Type–N_6: Thelycum of this type is also made up of two anterior and posterior embossed plates coming into contact with each other as in Type–N_5. But anterior plate is always provided with a strikingly developed apical acute spine directed somewhat antero-ventrally reaching beyond bases of third pereiopods. Posterior plate raised from posterior

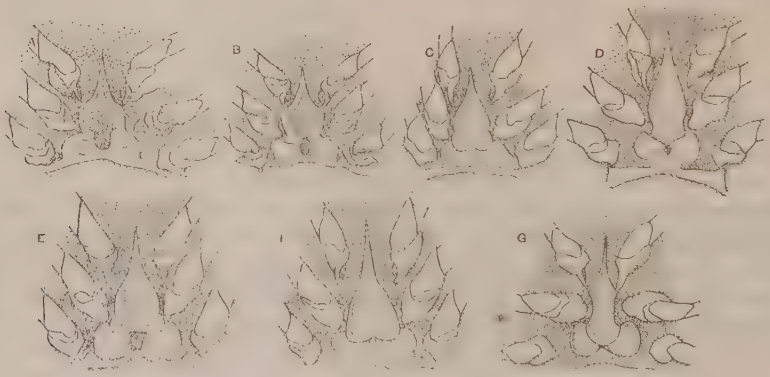

Fig. 48. Thelycum of Type-N_6. *A*, *Eusicyonia cristata*, 45 mm in body-length (15 mm in carapace-length), ×2; *B*, *E. lancifer japonica*, 56 (18), × 1.6; *C*, *E. nebulosa*, 30 (9), ×6; *D*. *E. inflexa*, 45 (19), × 2.4; *E*, *E. curvirostris*, 57 (16), ×2.4; *F*, *E. truncata*, 44 (12), ×2.4; *G*, *E. vitulans*, 40 (12), × 2.4.

border of the last thoracic sternite, much shorter than wide, and usually has a pit at middle of anterior border (Fig. 48). All species of *Eusicyonia* belong to this type.

Type–N_7: The last thoracic sternite has a rather small embossed median plate and a pair of lateral plates. Median plate does not extend beyond anterior bases of fourth pereiopods, usually much longer than wide, and located anterior to the lateral plates. Posterior rim of the last thoracic sternite is usually without median process (Fig. 47, *A–J*).

Metapenaeus, *Penaeopsis*, *Atypopenaeus* and *Trachypenaeopsis* are embraced in this group. The median process of posterior border of the last thoracic sternite is present in *Trachypenaeopsis richtersii* and *Penaeopsis rectactus* only.

Type–N_8: Sternite of the last thoracic segment has anteriorly a median process and posteriorly a large seminal receptacle. Anterior process is situated on sternite between fourth pereiopods, embossed with an apical protuberance which is variable in outline. Seminal receptacle occupies most part of the last thoracic sternite, is usually composed of

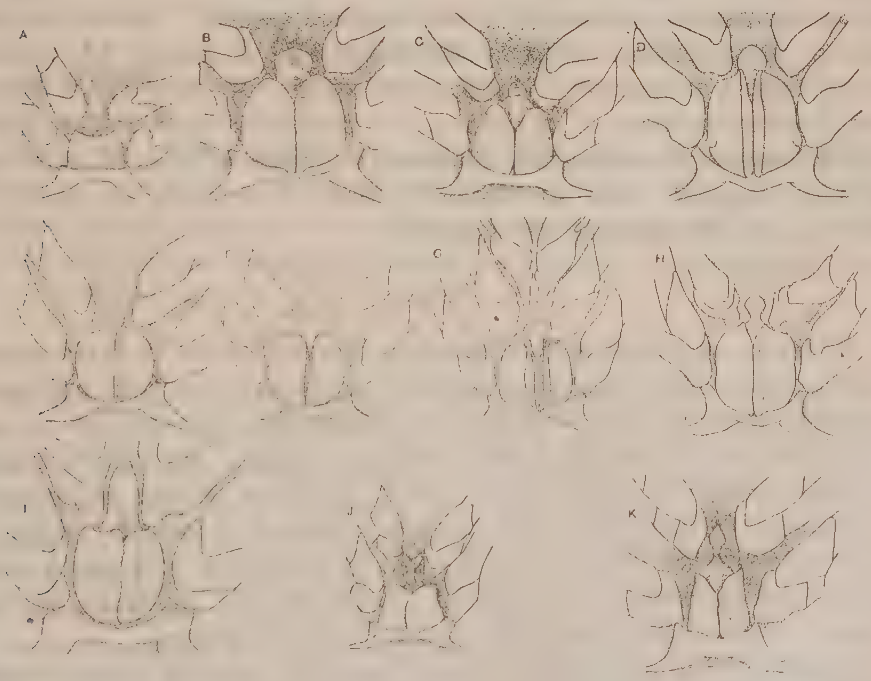

Fig. 49. Thelycum of Type-N_8. *A, Penaeus japonicus,* 105 mm in body-length (33 mm in carapace-length), ×2; *B, P. monodon,* 174 (40), ×1.6; *C, P. bubulus,* 135 (38), ×2; *D, P. orientalis,* 177 (52.5), ×1.6; *E, P. penicillatus,* 126 (32.5), ×2; *F, P. merguiensis,* 100.5 (25.4), ×2.4; *G, P. esculentus,* 135.5 (35), ×1.6; *H, P. brevirostris,* 114 (30), ×2.4; *I, P. longistylus,* 149.5 (44.5), ×3.2; *J, P. latisulcatus,* 118 (35.5), ×1.6; *K, P. teraoi,* 145 (42.5), ×2.

two lateral plates which come into contact with each other along median borders, and somewhat overlap anterior median process by its antero-median margins, and rarely cylindrical with entrance anteriorly. Posterior border of eighth thoracic sternite has no median protuberance (Fig. 49).

Represented by all Indo-Pacific species of *Penaeus* and a Pacific American species, *Penaeus brevirostris.*

The apical protuberance of the anterior median process is semicircular in outline usually with minute apical spine in *P. japonicus, P. monodon, P. bubulus, P. orientalis, P. penicillatus, P. merguiensis, P. indicus* and *P. brevirostris*, ogival in *P. logistylus*, bifuicate in *P. latisulcatus* and lanceolate in *P. teraoi.* The seminal receptacle is cylindrical in *P. japonicus* only.

b. Metamorphosis of thelycum of some species.

No report of this subject has been put on records as far as the writer is aware of. Thus the metamorphosis of thelycum has been traced of many specimens obtained from various localities of Japan. The specimens are represented by the annexed species: *Aristaeomorpha foliacea, Parahaliporus sibogae, Metapenaeopsis barbatus, M. acclivis, Trachypenaeus curvirostris, Metapenaeus affinis, M. joyneri, M. monoceros, Penaeus bubulus, P. monodon, P. latisulcatus, and P. japonicus.* Of these species, first two have thelycum referable to Type–N_3, third and fourth to Type–N_4, fifth to Type–N_5, those from sixth to eighth to Type–N_7, and the last four to Type–N_8.

1. Type–N_3.

Aristaeomorpha foliacea. In a female, 60 mm in body-length, which is the smallest specimen secured, thelycum has two prominent transverse plates already (Fig. 44, *C*). Of the two, anterior one is located on posterior border of penult thoracic sternite, directed obliquely anteriorly, rather abruptly pointed, about 1–2 times as long as (inclusive apical spine) as wide. Posterior plate is produced from the middle of sternite between the last pereiopods, acutely pointed at apex, much smaller than the anterior plate. Posterior border of the hindmost thoracic sternite is not elevated markedly, and has no appendages.

Passing to the next stage, 65 mm long, the anterior plate becomes considerably larger, and more or less ogival in outline reducing size and acuteness of the apical spine, but is still somewhat longer than wide. The posterior plate gets circular in outline minutely pointed at apex, still directed antero-ventrally, and a little shifts posteriorly compared with that of the preceding stage, 60 mm long. A pair of lateral spinous projections which lie at middle of the last thoracic sternite of adult do not yet make their appearande (Fig. 44, B).

In an adult, 148 mm in body-length, the anterior plate is subrectaugular with rounded apex, occupying entire width of sternite between fourth pereiopods, and directed somewhat antero-ventrally. The posterior plate becomes almost upstanding, arises from anterior margin of the posterior ridge of the last thoracic sternite, occupies about two-ninths the breadth of the sternite between the fifth pereiopods, is spindle-shaped in cross-section, and pointed at apex. The paired lateral upstanding spines set at middle of the last thoracic sternite are directed antero-laterally, with rather sharp apex, bar-shaped with reunded anterior and posterior margins in cross-section, and come into contact with postero-median edge of the fourth pereiopods. (Fig. 44, *A*).

Parahalipors sibogae. In the smallest individual among the females examined, 71 mm long, a narrow, well defined low ridge arising a little in front of the articulation between the last two thoracic sternites runs forward along median line, with acuminate tip reaching to about six-sevenths of the penult thoracic sternite. The last thoracic sternite is furnished with a rather defined narrow median elevation arising a little in front of posterior margin of the last thoracic sternite and reaching to four-fifths of the sternite on which it lies, and being acute spiniform at anterior end (Fig. 44, *F*).

When the animal attains a length of 90 mm, the thelycum seems to assume an adul form. In a specimen, 115 mm long, both anterior and posterior median ridges are well defined and sharp at anterior extremity, the posterior ridge extends to about two-thirds of the last thoracic sternite (Fig. 44, *E*).

2. Type-N_4.

Metapenaeopsis barbatus. Fig. 50, *B* represents thelycum of a specimen, 20 mm long, which is the smallest dealt with herein. The transverse plate raised from sternite between fourth pereiopods is directed antero-ventrally, subrectangular in outline, rounded at disto-lateral angles, armed with sharply pointed spine at middle of apical border, about 1.8 times as wide as long (excluding apical spine), and occupies about five-sixths the width of sternite between fourth pereiopods. The last thoracic sternite is provided already with a transverse ridge at the middle. The ridge is curved anteriorly at each lateral end, with anterior margin well defined and almost straight, and with posterior one hardly defined yet. The posterior ridge of eighth thoracic sternite is rather markedly raised with rounded apex on each antero-lateral fringe, and armed with short pointed spine directed antero-ventrally at middle of the anterior border.

At a stage with body-length of 36 mm, the transverse plate shows no marked difference in feature comparing with that of the preceding stage, 20 mm in body-length except the following poinsts: the plate occupies about nine-tenths the width of sternite between the penult thoracic legs, and the apical spine is smaller. The transverse ridge has anterior and posterior borders well defined, and curves with convex border anteriorly. The median process laid down on posterior ridge of the rearmost thoracic sternite becomes rather blunt at apex (Fig. 50, *C*).

In an adult male, 70 mm in body-length, the organ resembles that of the stage, 36 mm long, in general feature (Fig. 50, *D*). The transverse plate occupies entire width of the sternite between fourth limbs, the apical spine becomes smaller than that of the stage, 36 mm long. The transverse ridge of the last thoracic sternite gets considerably thickened at lateral angle with convex inner and wavy outer borders.

Metapenaeopsis acclivis. The thelycum of a specimen, 35.5 mm long, is well developed already (Fig. 50, *E*). The plate set on sternite between fourth pereiopods is rectangular in outline with rounded disto-lateral borders and an apical spinule, about twice as wide as long, direc-

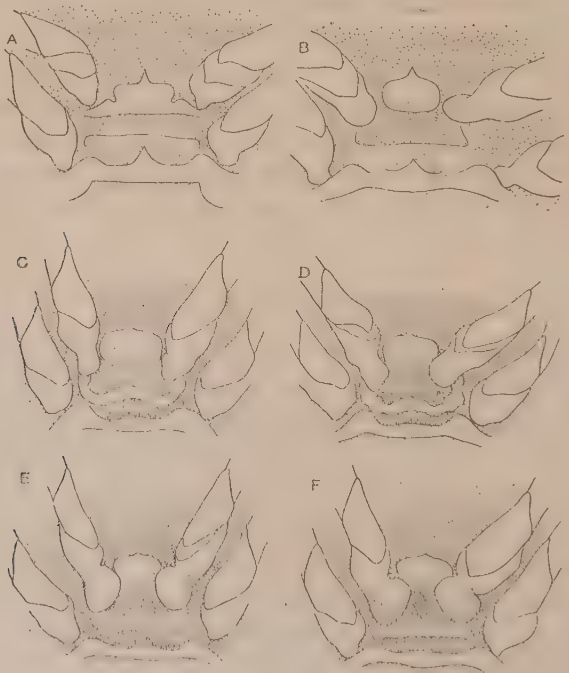

Fig. 50. Metamorphosis of thelycum of *Metapenaeopsis barbatus* (*A*-*D*) and *Metapenaeopsis acclivis* (*E* and *F*). *A*, 19.5 mm in body-length, ×20; *B*, 20, ×20; *C*, 36 mm in body-length (8 mm in carapace-length), ×7.5; *D*, 70 (16.5), ×3.5; *E*, 35.5 (8), ×7.5; *F*, 44.5 (11). ×6.

ted antero-ventrally, covers about three-fifths the width of sternite between fourth legs, The transverse ridge lies as a tumid ridge with straight anterior and posterior rims. The posterior ridge of the last thoracic sternite is provided with a process bluntly pointed at apex at middle of anterior rim, and a swelling runded at apex on each antero-lateral rim.

In a little advanced stage, 44.5 mm in body-length, the plate placed on sternite between fourth pereiopóds undergoes a little transformation in feature compared with that of the preceding stage, 35.5 mm in body-length, and occupies about nine-tenths the width of sternite between fourth legs. The transverse ridge lying at middle of the last thoracic sternite is still straight, with not yet sharply defined anterior border and already well defined posterior one. The posterior ridge of eighth thoracic sternite is similar to that of the preceding stage, 35.5 mm long.

In an adult female, 74,5 mm long, the plate set on sternite between fourth pereiopods is somewhat fig-shaped in outline, bearing a spinule at apex, and occupies almost entire of the sternite on which it lies. The transverse ridge running across middle of the last thoracic sternite bends with concave border posteriorly.

3. Type–N_5.

Trachypenaeus curvirostris. In a larval specimen measuring 18 mm long, thelycum is somewhat differentiated already (Fig. 51, *A*). Anterior plate which is raised from posterior border of penult thoracic sternite, is semicircular in outline, armed with a large sharply pointed spine at apex, directed anteriorly, somewhat less than twice as wide as long except apical spine, flat on ventral surface, occupies about two-thirds the width of sternite between fourth limbs. An ill-defined arcuate swelling with concave margin forward is present behind the anterior plate. A vestigial upstanding median boss rounded at apex is set a little posterior to the middle of the last thoracic sternite. Posterior plate raised from anterior border of posterior ridge of the last thoracic sternite is somewhat developed already, gradually increasing outward, provid at each antero-lateral angle with a swelling which is narrowed anteriorly and reches to about middle of the last thoracic sternite. Posterior rim of the rearmost thoracic sternite is slightly concave.

Upon reaching the stage, 25 mm in body-length, the thelycum shows remarkable modification in general aspect comparing that of the preceding stage, 18 mm long. The anterior plate becomes deltoid in outline with rounded corners, is somewhat shorter than wide measured in the broadest region, flattish on ventral surface, a little convex on posterior edge, slightly indent at posterior one-third of lateral edges, extending to anterior bases of fourth pereiopods and the middle of the last thoracic sternite. The arcuate swelling found behind the anterior plate in the preceding stage, 18 mm long, becomes hidden beneath the anterior plate. The median boss is fused with anterior margin of the posterior plate. The posterior plate is increased in length, with anterior border strongly concave and somewhat setose postero-laterally. The posterior margin of the last thoracic sternite gets double convex (Fig. 51. *B*).

In a specimen, 36 mm in body-length, the anterior plate is subrhombic in outline with corners rounded, somewhat wider than long, slightly concave on both lateral borders, extending to anterior bases of fourth pereiopods. The posterior plate is markedly lengthened, broadly and triangulary notched on anterior border, and somewhat overlaps the anterior plate; the postero-lateral setose areas are much widened. The posterior border of the hindmost thoracic sternite is double convex as in that of the stage, 25 mm in body-length (Fig. 51, *C*).

The organ of a specimen measuring 57 mm long does not differ much in general configuration from that of the stage, 36 mm long (Fig. 51, *D*). But it is modified from the latter in the following respects: antero-lateral borders of the anterior plate is almost straight; median notch of the anterior border of the posterior plate gets much narrower; and the setose areas become continuous.

The thelycum of a female, 72 mm long, varies little in general aspect compared with that of the stage, 57 mm long (Fig. 47, *K*).

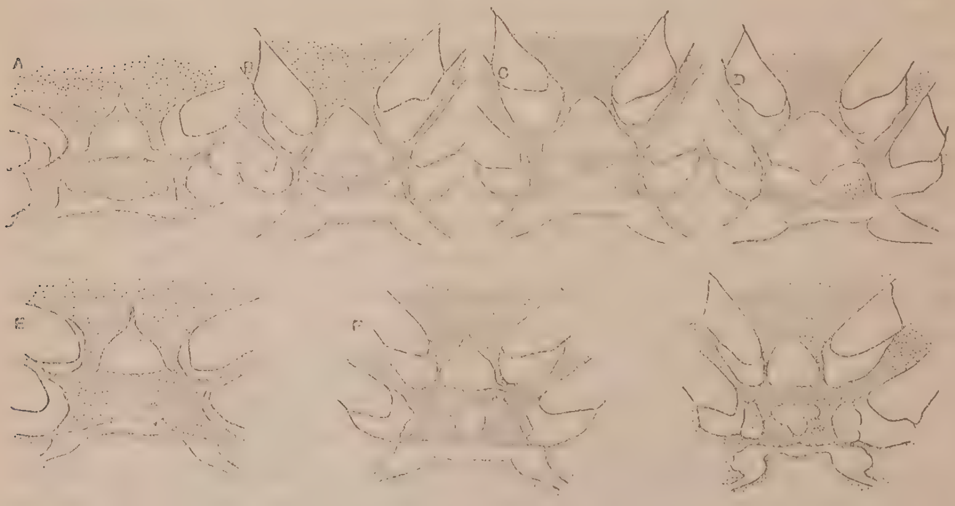

Fig. 51. Showing metamorphosis of thelycum (*A–D*) and that of last two thoracic sternites of male (*E–G*) of *Trachypenaeus curvirostris*. *A*, 18 mm in body-length (5.5 mm in carapace-length), ×22.5; *B*, 25 (6.8), ×15; *C*, 36 (9.5), ×10.5; *D*, 57 (15.5), ×6; *E*, 25 (8), ×22.5; *F*, 34 (9), ×15; *G*, 80 (22.5), ×10.5.

4. Type-N_7.

Metapenaeus affinis. Thelycum of a young, 25.6 mm long, is considerably differentiated already, consists of three elements, namely, anterior three longitudianal upheavals, posterior paired lateral projections, and posterior ridge of the rearmost thoracic sternite (Fig. 52, *A*). The anterior three longitudinal upheavals are embossed with ill-defined edges. The median upheaval is the longest, extending to middle of sternite between fourth pereiopods and to center of the last thoracic sternite, gradually narrowed anteriorly to a point in anterior one-third, rounded on posterior border, and slightly convex on lateral borders. The lateral upheavals are half as long as the median one, and extends to posterior border of the median one. The posterior paired lateral projections are horn-shaped, located a little in front of the posterior ridge of the last thoracic sternite, set somewhat antero-laterally, turning forward in distal one third, pointed at apex, reaching about middle of the last thoracic sternite, not yet fused with each other along median border. The posterior ridge of the eighth thoracic sternite is almost straight with slightly concave anterior and a trifle convex posterior rims.

At the time the prawn measuring 43 mm in body-length, the anterior upheavals are the same in feature as in those of the preceding stage, 25.6 mm long. The posterior projections are markedly increased in width with strongly concave inner and convex outer borders, fused with each other along median border in posterior about half and with anterior border of the posterior ridge of the last thoracic sternite in inner about one-third of posterior border, and reach a little beyond middle of the last thoracic sternite. The posterior ridge of the hindmost thoracic sternite is considerably thicker than that of the stage, 25.6 mm (Fig. 52, *B*).

In an adult form, 61 mm in body-length, the anterior upheavals are widened posteriorly, and approached each other. The posterior projections are strikingly increased in width, flattish on ventral surface, abruptly pointed at apex, directed antero-medially, extending to middle of the anterior lateral upheavals, fused entirely along median line. The posterior ridge of the last thoracic sternite undergoes no modification in feature compared with that of the stage, 43 mm long (Fig. 52, *C*).

Metepenaeus joyneri. In a young measuring 38.5 mm in body-length, thelycum is composed of an anterior median and a pair of posterior lateral swellings, and posterior ridge of the last thoracic sternite (Fig. 52, *D*). The anterior swelling is trifid anteriorly with median larger and lateral smaller lobes. The median lobe extends from middle of the last thoracic sternite to middle of sternite between fourth thoracic limbs, and narrows anteriorly. The lateral lobes are directed antero-laterally, acutely pointed at apex, reaching to about one-third of the median lobe. The posterior swellings are slender, arc-shaped in outline, raised a little in front of the posterior ridge of the last thoracic sternite, stretching a little beyond middle of the last thoracic sternite, with inner margin abruptly curved outward at apex. The posterior ridge of the eighth thoracic sternite is considerably broad with almost straight anterior and slightly convex posterior rims.

At a stage, 45 mm long, thelycum is modified in the lateral lobes of the anterior swelling and the posterior ones (Fig. 52, *E*). The lateral lobes get markedly larger than the median lobe, and extends as far as middle of the median lobe. The posterior swelling is remarkably increased in width, more or less widened anteriorly, rounded on anterior and posterior borders.

When the animal attains a length of 53 mm, the lateral lobes of the anterior swellings are fused with the median lobe, except its apical portion. The posterior swellings resemble those of the stage, 45 mm long, in feature, but remarkably widened with rather defined ventral border which displays some tendency to grow ventro-medially in anterior half. The posterior ridge of the last thoracic sternite is still almost

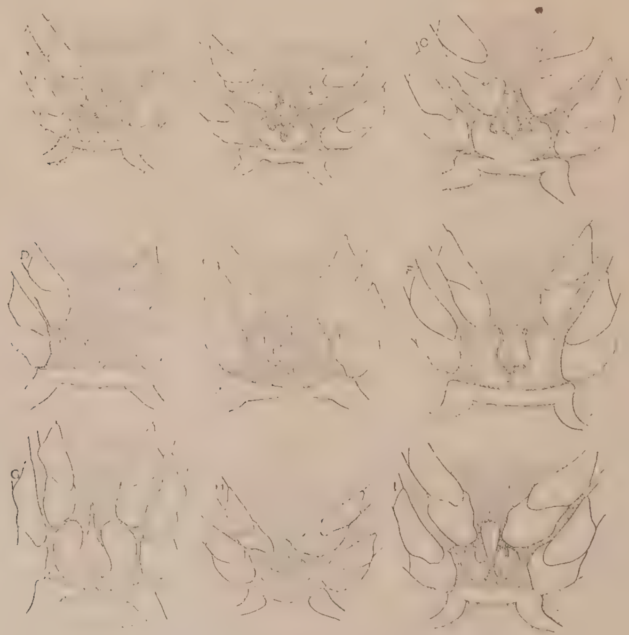

Fig. 52. Metamorphosis of thelycum of *Metapenaeus affinis* (*A-C*), *Metapenaeus joyneri* (*D-G*), and *Metapenaeus monoceros* (*H* and *I*). *A*, 25.6 mm in body-length (7 mm in carapace-length), ×8.4; *B*, 43 (10.5), ×6; *C*, 61 (17.4), ×4.8; *D*, 38.5 (9.5), ×8.4; *E*, 45 (12), ×6.4; *F*, 53 (17), ×6.4; *G*, 77 (20), ×3.2; *H*, 34 (10), 6; *I*, 58 (12), ×4.8.

straight with parallel anterior and posterior edges.

At the time the animal measures 77 mm in body-lenghth, thelycum almost assumes its adult form (Fig. 52, *G*). The anterior swelling is inverted racket-shaped in outline, pointed at apex, flattish on ventral surface, twice as long as wide measured in the widest region, and remarkably extends backward comparing with that of the stage, 57 mm long. The posterior swellings are strikingly expanded ventromedially in anterior half as a plate-like expansion with rounded antero-median border, smooth and convex on ventral surface, reach a little behind postero-median edges of fourth thoracic limbs and somewhat overlap the anterior swelling. The posterior ridge of the hindmost thoracic sternite curves with somewhat concave anterior and markedly convex posterior edges.

Metapenaeus monoceros. In a juvenile specimen, 34 mm in body-length, thelycum is considerably differentiated already (Fig. 52, *H*), and made up of three anterior longitudinal and a pair of posterior elevations as is the case with that of *Metapenaeus affinis*. Of the anterior three elevations, median one is much larger and more defined than others, ranging from about middle of the last thoracic sternite to middle of sternite between fourth pereiopods, measures about 0.7 mm in length, two and half times as long as wide measured near posterior end, is somewhat concave on lateral borders, rather suddenly narrowed in anterior subterminal portion with rounded apex, and rounded on posterior border; lateral elevations are ovoid in outline, extending from middle of the last thoracic sternite to half-way of the median elevation. The posterior elevations are similar to those of the stage, 25.6 mm long, of *Metapenaeus affinis* in general feature, situated more forward than those of *M. affinis*, sharply pointed at apex, directed antero-medially with semicircularly rounded outer border, ill-defined on median borders, and extend somewhat beyond middle of the last thoracic sternite. Posterior ridge of the rearmost thoracic sternite is somewhat arcuate with concave margin anteriorly.

On passing to more advanced stage, 58 mm in body-length, the anterior median elevation is tongue-like, gradually widended anteriorly and abruptly narrowed into a rounded apex, a little more than twice as long as wide measured in the broadest region, somewhat indent along median line. The anterior lateral elevations are hardly recognizable. The posterior elevations are well defined on median borders, not yet reaching to lateral edges of the anterior median elevation with considerable distance, a little channeled longitudinally on ventral surface.

In an adult female, 133 mm long, the anterior median elevation is somewhat less than twice as long as wide measured in the widest region, and minutely pointed at apex. The posterior elevations attain one-third of lateral edges of the anterior elevation, and are deeply channeled longitudinally with rather thin lateral walls, the inner wall being directed ventro-medially and outer one ventrally (Fig. 47, *B*).

5. Type–N_8.

Penaeus bubulus. In a young female, 28.5 mm long, seventh thoracic sternite has a rather low elevation between fourth pereiopods, and more or less tumid posterior border. Eighth thoracic sternite carries an inconspicuous pyramidal elevation with apex a little posterior to the middle and two surfaces postero-laterally, and well defined almost straight posterior ridge with parallel anterior and posterior rims (Fig. 53, *A*).

Thelycum of a specimen, 38 mm in body-length, consists of one anterior, paired two posterior projections, and posterior ridge of the last thoracic sternite, whilst the pyramidal elevation found on the last thoracic sternite of the preceding stage, 28.5 mm long, has faded away already (Fig. 53, *B*). The anterior projection is formed by fusion of two parts which are found in the stage, 28.5 mm long, as a conical elevation set on sternite between fourth periopods, and a transverse swelling along posterior border of penult thoracic sternite, provided with rounded anterior margin and a little wavy posterior one which is produced backward behind each inner basal margin of fourth pereiopods. The posterior projections are triangular in outline, raised from anterior rim of posterior ridge of the last thoracic sternite, with inner margin running antero-laterally from a point a little outer to median line toward

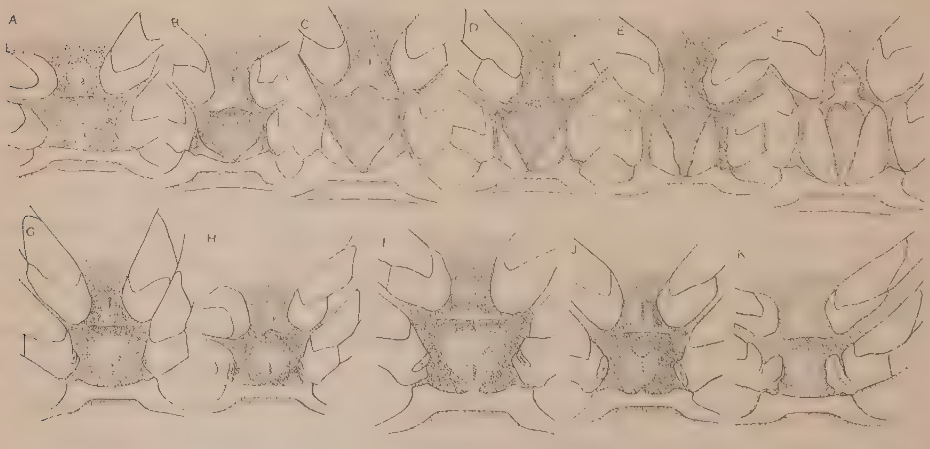

Fig. 53. Transformation of thelycum (*A–F*) and that of last two thoracic sternites of male (*G–K*) of *Penaeus bubulus*. *A*, 28.5 mm in body-length (8 mm in carapace-length), ×12; *B*, 38 (10), ×8.4; *C*, 49 (13.5), ×8.4; *D*, 55 (15.6), × 6; *E*, 65.5 (18), ×4.8; *F*, 78 (22.5), ×4.5; *G*, 42 (10.6), ×8.4; *H*, 55 (14.5), ×6; *I*, 52 (13.5), ×8.4; *J*, 70.5 (21.5), ×4.8; *K*, 102 (27.6), ×2.4.

about middle of the last thoracic sternite. The posterior ridge of the last thoracic sternite has somewhat concave anterior and straight posterior rims.

In the stage 49 mm long, the thelycum a little shows transformation (Fig. 53, *C*). The posterior border of the anterior projection is markedly concave. The posterior projections are lamellar, somewhat widened and lengthened, and reach a little beyond middle of the last thoracic sternite. The anterior rim of the posterior ridge of the rearmost thoracic sternite is remarkably concave.

When the prawn measures 55 mm in body-length, the anterior projection is markedly elevated, the posterior border is more or less produced postero-ventrally. The posterior projection is also lifted ventrally, somewhat convex on ventral surface, almost extending to lateral foot of posterior border of the anterior projection. The posterior ridge of the last thoracic sternite possesses anterior concave and posterior straight rims as in that of the preceding stage, 49 mm in body-length (Fig. 53. *D*).

At 65 mm stage, posterior border of the anterior projection is greatly concave, and provided with a small pointed protuberance which is directed backward at middle.

The posterior projections are much increased in size, ogival in outline in anterior half, 2.5 times as long as wide, and overla plateral feet of the anterior projection (Fig. 53, *E*).

As illustrated in Fig. 53. *F*, the anterior projection of a specimen, 75 mm in body-length, is well defined with a large process which is inserted on anterior border, directed forward, and pinhead-shaped in outline; the pointed protuberance set on the posterior median border gets markedly prominent, and the postero-lateral border is considerably raised medially. The posterior projections are subtriangular in outline with almost straight median edge running anterolaterally, slightly convex on outer edge, and rounded apex twice as long as wide, and overlap about outer half of postero-lateral lobes of the anterior projections.

When the prawn attains 90–100 mm long, seminal receptacle is completed as the posterior projections come into contact with each other along median line, and the thelycum reaches its adult form.

Penaeus monodon. A young female, 26 mm in body-length, has thelycum hardly differentiated (Fig. 54, *A*). Posterior two thracic sternites closely resemble those of the stage, 28.5 mm long of *Penaeus bubulus* in general aspect. The posterior ridge of the last thoracic sternite has a pair of triangular outgrowths, which are rudiments of seminal receptacle, at a quarter of anterior rim.

At the stage, 29 mm long, sternite of seventh thoracic segment has an inverted T-shaped low swelling as the sternite is swollen along median line posterior to sternal spine set between fourth pereiopods, and is swollen along posterior border which is slightly concave. Sternal spine of eighth thoracic sternite persists as a pyramidal process and is situated a little behind center of the sternite. The rudiments of seminal receptacle are a little developed with a minute sharply pointed process which is directed antero-medially at distal inner angle (Fig. 54, *B*).

In a specimen, 37 mm in body length, posterior border of the T-shaped swelling of seventh thoracic sternite is remarkably concave. Sternal spine of the last thoracic sternite is much reduced. The rudiments of seminal receptacle are slender, narrowed anteriorly with acute end, and directed antero-medially extending to about middle of the last thoracic sternite (Fig. 54, *C*).

As exhibited in Fig. 54, *D*, thelycum of a specimen, 42.3 mm long, is made up of an anterior projection and a pair of rudiments of seminal receptacle or posterior projections like that of the stage, 38 mm long, of *Penaeus bubulus*. The anterior and posterior projections closely resemble those of the stage, 38 mm long, of *P. bubulus* in general configuration. The sternal spine of the last thoracic segment is hardly recognizable.

In a specimen, 50 mm long, the anterior projection is remarkably upheaved, posterior border becomes shelf-like with a large rectangular median notch which is twice as wide as long with a convex swelling directed backward on median border. The posterior projectrons are

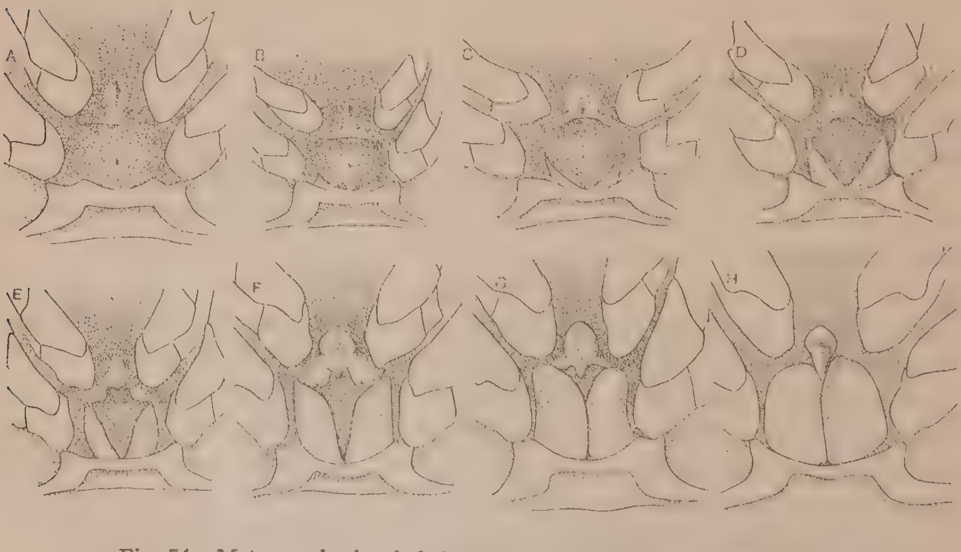

Fig. 54. Metamorphosis of thelycum of *Penaeus monodon*. *A*, 26 mm in body-length (7 mm in carapace-length), ×15; *B*, 28 (7.5), ×10.5; *C*, 37 (9.5), ×10.5; *D*, 42.3 (11.5), ×7.5; *E*, 50 (13.2), ×7.5; *F*, 70 (18.4), ×6; *G*, 78 (20.5), ×4; *H*, 120 (31), ×3.5.

lamellar, somewhat ogival in outline, twice as long as wide, more or less convex on ventral surface, pointed at anterior end, and reach outer posterior border of the anterior projection. Inner margin is straight, running antero-laterally at an angle of about 60° and turns more strongly outward (Fig. 54. *E*).

On reaching the stage, 70 mm long, the anterior projection is provided with well defined anterior median protuberance and posterior shelf. The anterior median protuberance is cardifom in outline, rounded at apex, somewhat wider than long. The porterior shelf is markedly increased in width, the median rectangular notch is much narrowed, and the process arising from the median border of the notch reaches to about middle of the lateral border of the notch. The posterior projections are much widened, subrhombic in outline, a little less than twice as long as wide, pointed at apex and extend a little behind posterior base of fourth pereiopods; inner border runs antero-laterally at an angle of about 80° and turns outward with a bending of about 45° at three-fifths (Fig. 54, *F*).

In the stage, 78 mm long, the anterior protuberance of the anterior projection is as long as wide, round at apex, flattish on ventral surface. The median notch of the posterior border of the anterior projection is not recognizable, since the process set on median border of the notch is much increased in size, reaching well beyond the end of lateral border of the notch. The posterior projections are rounded at apex, and come into contact with each other along median borders in proximal two-thirds. Still there exists a V–shaped narrow gap between the anterior and posterior projetions (Fig. 54, *G*).

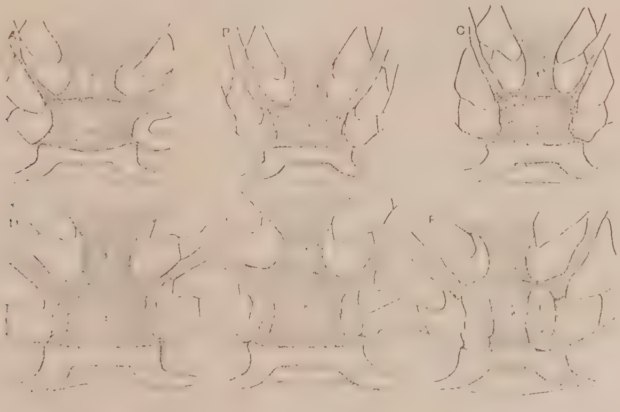

Fig. 55. Metamorphosis of last two thoracic sternites of male of *Penaeus monodon*. *A*, 24.7 mm in body-length (7 mm in carapace-length), ×12; *B*, 41 (11.1), ×6; *C*, 45.2 (12.5), ×6; *D*, 58 (15), ×6; *E*, 76 (20), ×4.8; *F*, 118 (31), ×2.8.

The thelycum of a specimen, 120 mm in body-length, is almost completed (Fig. 54, *H*). Of the anterior projection, the posterior process is greatly lengthened, and extends as far as anterior one-fourth of the posterior projections, but still exposed. The posterior projections completely meet with each other along median border, and overlap lateral feet of the anterior projections.

***Penaeus latisulcatus*:** Thelycum of a female, 39,5 mm in body-length, is in a considerably advanced condition with anterior swelling and posterior projections (rudiments of seminal receptacle) as in that of *Penaeus bubulus*, and *P. monodon* (Fig. 56, *A*). The anterior swelling again consists of anterior and posterior parts. The anterior part is inverted T-shaped, laid down on sternite between fourth pereiopods, the longitudinal arm of the T is semicircular in outline occupying about three-fifths the width of the sternite on which it lies, and the transverse arm of the T is narrow, running along posterior edge of penult thoracic sternite. The posterior part is placed along anterior edge of the last thoracic sternite, a little wider than the transverse elevation of the anterior part, and double concave, with a median protrusion bearing rounded apex on posterior border.

The posterior projections are plate-like, triangular in outline, with almost straight outer margin and somewhat convex inner one which runs antero-laterally at an angle of about 60°, 1.5 times as long as wide measured at base, and extend somewhat beyond middle of the last thoracic sternite.

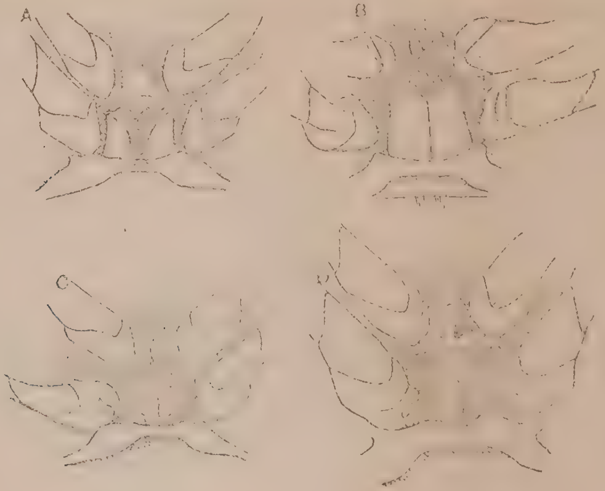

Fig. 56. Metamorphosis of thelycum (*A* and *B*) and posterior two thoracic sternites of male (*C* and *D*) of *Penaeus latisulcatus*. *A*, 39.5 mm in body-length (10.5 mm in carapace-length), ×9; *B*, 87.5 (22.5), ×4.2; *C*, 36 (10.2), ×9; *D*, 46.5 (13), ×9.

When the animal attains a length of 87.5 mm in body-length, thelycum almost assumes its adult form in general feature (Fig. 56. *B*). The anterior swelling is anteriorly provided with two pointed horns somewhat diverging forward, and posteriorly an inverted V–shaped upheaval. Median borders are straight and come into contact with each other. Outer borders are slightly indent at two-thirds. A terior ones lie antero-laterally at an angle of about 30°, a trifle concave; antero-median borders rounded.

Penaeus japonicus. In a specimen, 22.5 mm long, thelycum is made up of sternal spines of posterior two thoracic segments, a rather narrow transverse prominence running along anterior border of the last thoracic sternite, and a pair of projections laid down on the last thoracic sternite arising from posterior ridge of the sternite in question. The sternal spine of fourth thoracic segment is located between fourth pereiopods, sharply pointed at apex, and extends to anterior bases of fourth limbs. That of fifth thoracic sternite is set between the last pereiopods, acuminate at apex, but smaller than that of fourth thoracic somite. The projections attached to the last thoracic sternite are thin decreasing in width anteriorly, pointed at apex, arise from outer one-fourth of posterior ridge of the last thoracic sternite, run antero-laterally, rather abruptly turn anteromedially at apex, and reach to about middle of the last thoracic sternite (Fig. 57, *A*).

At the stage, 33 mm in body-length, sternal spine of seventh thoracic segment remains rather defined with blunt apex, and that of the eighth also rather defined and much decreased in size. The transverse tumid area of the last thoracic sternite gets somewhat wider than that of the preceding stage, 23.5 mm long. The projections raised from posterior ridge of eighth thoracic sternite are U–shaped in general aspect, and each is rather suddenly narrowed into a point and directed antero-laterally at apex, and reaches a little beyond middle of the last thoracic sternite (Fig. 57, *B*).

Upon passing to the stage, 44 mm long, thelycum consists of anterior elevation and posterior projections as in that of the stage, 33 mm long, of *Penaeus bubulus* and the stage, 42.3 mm long, of *Penaeus monodon*, since the sternal spine of the last thoracic segment is vanished (Fig. 57, *C*). The anterior elevation is formed by fusion of sternal spine of seventh thoracic segment and the swelling set along anterior border of the last thoracic sternite, broad, and inverted T–shaped in outline. Each of the posterior projections are narrow, arc-shaped, pointed at apex, stretching a little beyond middle of the rearmost thoracic sternite as that of the stage, 33 mm long.

In a specimen, 57 mm long, the anterior elevation is rounded on both anterior and posterior borders, irregular but rather defined on lateral borders. The posterior projections become harp-shaped in general feature with posterior border which is remarkably raised antero-ventrally as a lamellar expansion and forms a lumen. Each arm of the harp is rather narrow, pointed at apex, directed antero-medially in proximal half and antero-laterally in the rest, reaching somewhat behind the anterior elevation (Fig. 57, *D*).

Thelycum of a female, 73 mm in body-length, is illustrated in Fig. 57, *E*. The anterior elevation is markedly upheaved with inverted pear-shaped apical surface. The posterior projections which form seminal receptacle is somewhat cylindrical, gradually reducing its size distally with elliptical opening anteriorly, having a small roundtopped protuberance at middle of posterior border; antero-dorsal ends nearly reach to posterior edge of the anterior elevation.

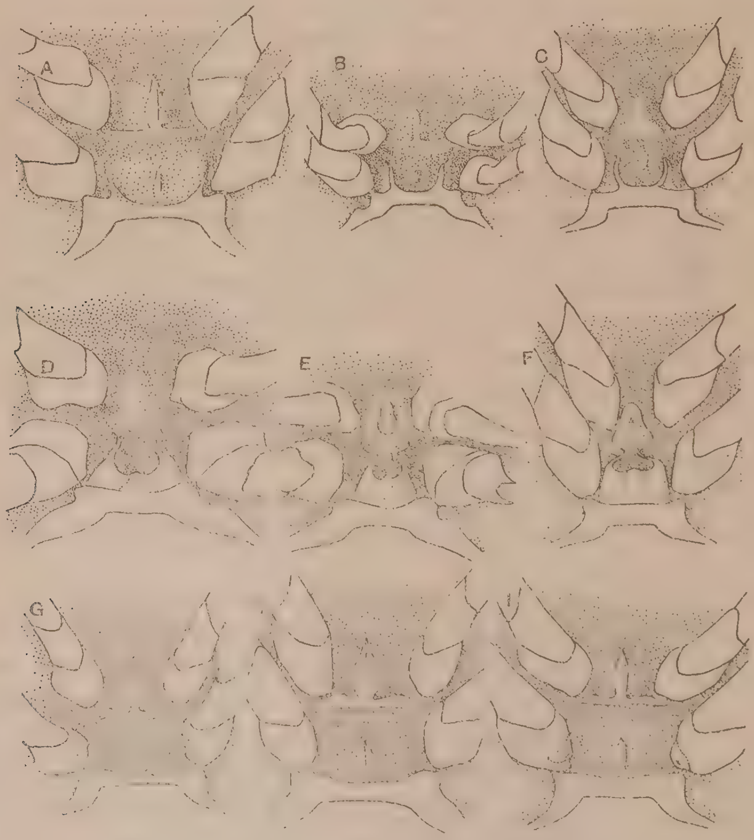

Fig. 57. Metamorphosis of thelycum (*A–F*) and posterior two thoracic sternites of male (*G–I*) of *Penaeus japonicus*. *A*, 22.5 mm in body-length (6.5 mm in carapace-length, ×18; *B*, 33 (9.8), ×9; *C*, 44 (14), ×7.2; *D*, 57 (16), ×7.2; *E*, 73 (22, ×4.2; *F*, 95 (29), ×3; *G*, 19.5 (6), ×18; *H*, 22.6 (6.5), ×18; *I*, 33.6 (10), ×12.6.

In a specimen, 95 mm long, the anterior elevation is well defined. The seminal receptacle is somewhat depressed, a little narrowed anteriorly, about twice as long as wide, more or less convex on anteroventral border, but the antero-dorsal ends do not come into contact with each other (Fig. 57, *F*).

Thelycum of a female, 105 mm long, almost assumes its adult form in general aspect (Fig. 49, *A*). The anterior elevation becomes somewhat triangular in outline with rounded anterior border, and flattish on ventral surface in anterior half, and elliptical in outline and convex on ventral surface in the rest. The seminal receptacle is completely cylindrical, depressed with elliptical entrance anteriorly, extending to posterior base of the anterior elevation, a little more than 1.5 times as wide as long, furnished with an ill-defined narrow swelling on ventral surface along median line. The swelling laid down on ventral surface is markedly convex at anterior end.

Remarks: Summarizing the descriptions given above, the annexed facts may be mentioned. In metamorphosis, the thelycum of *Metapenaeopsis barbatus*, *Trachypenaeus curvirostris*, *Penaeus bubulus*, *P. monodon*, *P. latisulcatus*, and *P. japonicus* starts from a condition closely resembling sternal aspect of the posterior two thoracic segments of male (Figs. 50, 51, 53–57). The prominence lying on sternite between fourth pereiopods of the following species is differentiated from sternal spines of seventh thoracic sternite, viz., *Aristaeomorpha foliacea*, *Parahaliporus sibogae*, *Metapenaeopsis barbatus*, *Trachypenaeus curvirostris*, *Penaeus bubulus*, *P. monodon*, *P. latisulcatus*, and *P. japonicus*. In this connection it may be noticed that the anterior plate of the thelycum referable to Type–N_6 (*Eusicyonia*) is perhaps differentiated from sternal spine of penult thoracic segment as in that of the Penaids given above judging from the general feature. The sternal spine of the last thoracic segment of *P. bubulus*, *P. monodon*, *P. latisulcatus*, *P. japonicus*, and *T. curvirostris*, vanishes at a rather early stage of development of thelycum. But the spine in question of *A. foliacea*, *P. sibogae*, *M. barbatus* persists as a pointed median process on posterior ridge of the last thoracic sternite even in adult form. Thus the conditions having acuminate process on the posterior ridge may be considered as a primitive state. Such may be also taken a primitive one as the feature in adult form having a strikingly developed spine on apical border of the transverse plate lying on sternite between fourth pereiopods, since the spine is very prominent in younger forms of *A. foliacea*, *M. barbatus*, and *T. curvirostris*.

The posterior plate of thelycum of *T. curvirostris* greatly diffars from the seminal receptacle of *P. bubulus*, *P. monodon*, and *P. japonicus* in feature of adult form. However, they are very similar in process of formation as set forth already. In initial condition, only difference lies in origin of the rudiment, viz., it arises from both lateral ends of posterior ridge of the last thoracic sternite in *T. curvirostris*, from outer one-fourth of the ridge in *P. bubulus*, *P. monodon* and *P. japonicus*. Unfortunately the metamorphosis of the thelycum of any species of *Eusicyonia* has not yet been worked out. But judging from general feature of adult thelycum of *Eusicyonia*, it may be said that the organ of *Eusicyonia* and *Trachypenaeus* is perhaps very similar or equal in category of formation.

Seminal receptacle is made up of two lateral lobes in *P. bubulus*, *P. monodon*, but a single, depressed, cylindrical object with its entrance opening anteriorly in *P. japonicus*. But they are equal in incipient condition as described already. BURKENROAD (1934, p. 89) has suggested dealing with *Penaeus brasiliensis* LATREILLE: "this type of thelycum is modified in *P. japonicus*, by the median fusion of the lateral plates or more probably, by the shifting forwards of the posterior margin of the U-shaped elevation,......". The present author's investigation appears to support his second alternative. At any rate, it seems probable that the *japonicus*-condition of seminal receptacle is more highly specialized than the *bubulus*-condition, although these two different types are diverged from the same phylogentical root.

In mode of formation, the thelycum of *Metapemaeus affinis*, *M. monoceros*, and *M. joyneri* is equal, but essentially differs from that of *T. curvirostris*, *P. bubulus*, *P. monodon*, *P. latisulcatus* and *P. japonicus* in the following respects: the anterior median elevation of these species of *Metapenaeus* is not originated from sternal spine of seventh thoracic segment; and a pair of posterior lateral projections are not raised from posterior ridge of the last thoracic sternite.

Finally it should be noticed that the sexual organ seems to attain its adult form at the time measuring about 40 mm in body-length in *M. barbatus*, and *M. acclivis*, 50 mm in *T. curvirostris*, 65 mm in *M. affinis*, 85 mm in *M. joyneri*, 90 mm in *M. monoceros*, and 100 mm in *A. foliacea*, *P. sibogae*, *P. bubulus*, *P. monodon*, *P. latisulcatus*, and *P. japonicus*. OHSIMA and YASUDA (1932, p. 140) say in ecological study of *M. affinis* that the female of this prawn reaches its biological minimum size when the animal measures about 62 mm long. It follows, therefore, that the integration of the thelycum of *M. affinis* takes place hand in hand with its sexual maturity.

c. Phylogenetical and taxonomic considerations of thelycum.

Basing on the general feature, the thelycum of all the species dealt with herein is tentatively classified into the eight groups, Types, N_1–N_8, as given already. The following phylogenetical consideration of thelycum is mostly based on morphological resembrance of thelycum and facts revealed by the investigation on the metamorphosis of the organ.

With regard to the phylogeny, four main stems, A–D, arising from a common ancestor may be recognized. The stem–A is represented by the Types, N_1–N_3, the stem–B by the Type–N_4, the stem–C by the types, N_5, N_6 and N_8, and the stem–D by the Type–N_7. The types which belong to the stem–A, are primitive, since the thelycum of these types are typically composed of anterior and posterior plates originated from sternal spines of the seventh and eighth thoracic segments. Type–N_1 may be the most primitive throughout all the types. The most primitive feature of the organ may be seen in *Parahaliporus sibogae*. The thelycum of *P. sibogae* consists of pointed median ridges which are little modified in feature from the corresponding sternal spines. The type–N_2 is similar to the type–N_1 in many respects. The type–N_3 is much simpler in general aspect than type–N_1, but the simplicity seems to be due to retrogression of transverse plates lying on sternite between fourth pereiopods and between fifth ones.

The type–N_4, which is only representative of stem–B, is linked with the types, N_1–N_3, referable to stem–A, in possession of a conspicuous transverse plate which is probably, at least in *Metapenaeopsis barbatus*, transformed from the sternal spine of the penult thoracic segment as in that of types of stem–A. But it is more specialized than the types N_1–N_3, in having a ridge across the last thoracic sternite.

The types, N_5, N_6 and N_8, ascribable to the stem–C, are characterized by bearing an anterior embossed elevation or plate and a posterior plate or a pair of lateral projections. They are related, however, with types, N_1–N_4, in possession of an embossed protuberance or broad plate which is placed on sternite between the fourth limbs. It appears to the writer that these types are more highly specialized than the types, N_1–N_4, and the type–N_6 is nearer to the type–N_5 than to the type–N_8. The anterior prominent plate with a large sharply pointed apical spine and posterior transverse plate which is expanded anteriorly from the postirior ridge of the last thoracic sternite of the type–N_6 are perhaps homologous with anterior broad plate and the posterior transverse plate raised anteriorly from posterior ridge of the rearmost thoracic sternite of the type–N_5 respectively. The thelycum of the type–N_8 strikingly differs from that of the type–N_5 in having well developed seminal receptacle. But the receptacle of the former type and the posterior transverse plate of the latter one is equal in mode of formation as already stated elsewhere.

The stem–D appears to be much diverged from others, stems–A–C, in the following respects: both anterior and posterior prominences of the type–N_7 (which is only representative of this stem) are not originated from the sternal spines of the last two thoracic somites; and the posterior prominence of the type-N_7 is not raised from posterior ridge of the hindmost thoracic sternite.

The following key is prepared to reveal more minutely the inter-relationship among the types, and even species, and to answer the taxonimic purpose.

Key to the species according to the types of thelycum.

A$_1$ A transverse plate, or a longitudinal narrow ridge with acute anterior end present on sternite between fourth pereiopods; the last thoracic sternite has no or hardly developed upheaval, or well defined narrow longitudinal ridge with sharply pointed anterior end; posterior edge of the last thoracic sternite with or without rather developed protuberance ....Type-N_1.

- B$_1$ Posterior two thoracic sternites without narrow median ridge; a transverse plate present on sternite between fourth pereiopods
  - C$_1$ Transverse plate lying on sternite between fourth legs subrectangular in outline, about 1.5 times as long as wide; the hindmost thoracic sternite flattish on outer surface; posterior ridge of the last thoracic sternite has a small median protuberance which is elliptical in outline, but minutely pointed at apex ....*Aristaeomorpha foliacea.*
  - C$_2$ Transverse plate set on sternite between fourth pereiopods subovoid in outline, about 1.3 times as wide as long; the rearmost thoracic sternite obscurely swollen forward along median line from about center, posterior ridge has a round-topped median upheaval ....*Aristaeus virilis.*
- B$_2$ Last two thoracic sternites have a narrow median ridge which is acuminated at tip; transverse plate absent on sternite between fourth pereiopods ....*Parahaliporus sibogae.*

A$_2$ Median projection laid down on sternite between penult thoracic limbs present or absent; if present, a cusp concavo-convex with convex surface forwards; the last thoracic sternite provided with a prominent pyramidal elevation or a pair of upstanding transverse walls which are thin, concavo-convex, with convex surface posteriorly (Coxal plates of last two pereiopods or those of fourth ones strikingly developed) ....Type-N_2

- D$_1$ Median projection situated on sternite between fourth pereiopods absent; the last thoracic sternite furnished with a conspicuous pyramidal elevation *Penaeus stylirostris.*
- D$_2$ A median cusp present on sternite between penult thoracic legs; the hindmost thoracic sternite has a pair of thin transverse walls at about middle ....*Penaeus vannamei.*

A$_3$ Thelycal sternites without outstanding prominences, but sometimes have obscurely or hardly developed prominences. (Coxal plate of fourth and fifth pereiopods not developed) Type-N_3

- E$_1$ The last thoracic sternite flattish, with no prominence.........*Solenocera faxoni.*
- E$_2$ The last thoracic sternite provided with ill-developed prominences.
  - F$_1$ A quadrate area bounded by narrow low ridges present on the last thoracic sternite
    - G$_1$ Sternite between fourth pereiopods without prominence; the quadrate area of the last thoracic sternite has a low conical elevation ....*Solenocera subnuda.*
    - G$_2$ Sternite between fourth pereiopods furnished with a prominence which is narrowed distally and emarginate at apex; the quadrate

area lying on the last thoracic sternite without elevation

H1 Median prominence placed on sternite between fourth limbs small, about one-third as long as wide measured at base; anterior border of the quadrate area of the last thoracic sternite does not reach to posterior base of fourth pereiopods; posterior edge of the hindmost thoracic sternite has a triangular projection which is emarginate on apical border, one-fourth as long as wide measured at base ....*Solenocera prominentis.*

H2 Median prominence set on sternite between fourth limbs trapezoidal in outline, somewhat emarginate at apex, half times as long as wide measured at base; anterior rim of the quadrate area of the last thoracic sternite attains posterior base of penult thoracic legs; posterior ridge of the last thoracic sternite devoid of median upheaval ....*Solenocera depressa.*

F2 Quadrate area bounded by low narrow ridges on the last thoracic sternite absent

I1 The last thoracic sternite furnished a little behind posterior bases of fourth pereiopods with a transverse swelling which is double-convex on posterior border, and furnished near middle with a swollen area which is convex on anterior edge, and trilobate on posterior one.........*Solenocera brevipes.*

I2 The last thoracic sternite has an arc-shaped transverse elevation near middle ....*Solenocera prominentis.*

A4 Sternite between fourth pereiopods has a prominent transverse plate which is raised antero-ventrally or merely embossed; the last thoracic sternite is traversed across about middle by a ridge which is either sometimes provided with projections at each lateral end as well as at middle of anterior border, or turns forward at each lateral end; posterior ridge of the rearmost thoracic sternite sometimes bears a triangular projection at middle ....Type-N_4

J1 Transverse plate laid on sternite between fourth thoracic pereiopods considerably raised antero-ventrally, with a minute spine at middle of apical border, posterior margin does not extend backward to middle of the last thoracic sternite

K1 Transverse ridge lying on the last thoracic sternite curves anteriorly at each lateral end, and has no projections

L1 Width of transverse plate located on sternite between fourth legs a little less than distance between both inner margins of coxal plates of fourth limbs ....*Metapenaeopsis barbatus.*

L2 Width of transverse plate set on sternite between penult pair of pereiopods about one-third the distance between inner margins of coxal plates of fourth legs ....*Metapenaeopsis acclivis.*

K2 Transverse ridge of the hindmost thoracic sternite has a pointed spine or a rectangular projection at each lateral end

M1 Apical border of transverse plate set on sternite between fourth thoracic limbs has a minute spine at middle; spine lying at each outer end of transverse ridge of the last thoracic sternite large in size, pointed at tip; posterior edge of the hindmost thoracic sternite has at middle a triangular process directed a little antero-ventrally *Metapenaeopsis dalei.*

M2 Apical margin of transverse plate set on sternite between fourth pereiopods has a minute spine at middle; lateral spine of transverse ridge of the hindmost thoracic sternite small in size;

posterior edge of the last thoracic sternite without spinous process ....*Metapenaeopsis incomptus.*

M_3 Apical rim of transverse plate laid down on sternite between fourth limbs provided at middle with a sharply pointed, rather long spine; transverse ridge of the last thoracic sternite armed at each outer end with a prominence which is rectangular in outline and rounded on apical border, and provided at middle of anterior edge with a projection which is subrectangular in outline, double-convex on distal border; posterior edge of the last thoracic sternite has a small acute spine at middle ....*Metapenaeopsis lamellatus.*

J_2 Median plate placed on sternite between fourth pereiopods broad, embossed, flat on ventral surface, posterior margin extends backward to at least about middle of the rearmost thoracic sternite

N_1 Posterior border of the plate situated on sternite between fourth pereiopods rightangularly pointed at middle, reaches to about middle of the last thoracic sternite; transverse ridge of fourteenth sternite broad, somewhat indent medially, provided with a quadrate prominence at each lateral end (Coxal plate of fourth pereiopods well developed). *Metapenaeopsis latus.*

N_2 Posterior border of the plate lying on sternite between fourth thoracic legs is emarginate, and reaches beyond middle of the last thoracic sternite; transverse ridge of the hindmost thoracic sternite has an inverted L-shaped prominence at each outer end. (Coxal projection of fourth pereiopods not developed) ....*Metapenaeopsis coniger.*

A_5 Anterior plate usually broad, embossed, anterior margin armed or unarmed at middle with long sharply pointed projection directed almost anteriorly, posterior border extends at least to about middle of the last thoracic sternite and comes into contact or sometimes is fused with anterior border of posterior plate which is raised from posterior ridge of the last thoracic sternite (Coxal projections of last two pairs of pereiopods absent)

O_1 Anterior plate without long, acutely pointed projection on anterior border ....Type-N_5

P_1 Posterior elevation a little overlaps anterior plate forming an imcomplate seminal receptacle

Q_1 Anterior plate subrhombic in outline ....*Trachypenaeus curvirostris.*

Q_2 Anterior plate semicircular in outline ....*Trachypenaeus asper.*

P_2 Posterior plate comes into contact with anterior plate, but does not overlap anterior one

R_1 Anterior plate very large, and extends posteriorly beyond middle of the last thoracic sternite

S_1 Anterior plate subrhombic, with anterior border rather broadly rounded as long as wide measured at the widest region; posterior plate deeply emarginate on anterior border, and has a pair of narrow depression along anterior border ....*Parapenaeopsis tenellus.*

S_2 Anterior plate subrectangular in outline

T_1 Anterior plate somewhat widened posteriorly, rounded on anterior border, as long as wide measured in the broadest region; posterior plate much wider than anterior plate, furnished with an inverted fig-shaped swelling at middle near posterior edge, consists of a pair of rather broad lobes, each of which is rounded at apex, directed antero-laterally; a tuft of long hairs exists at middle just behind posterior ridge of the last thoracic sternite ....*Parapenaeopsis cornutus.*

T$_2$ Anterior plate slightly emarginate on distal border, 1.7 times as long as wide; and arises somewhat in front of posterior edge of the last thoracic sternite; posterior plate narrow, curves anteriorly at each lateral end, and reaches to about middle of anterior plate ....*Parapenaeopsis hungerfordi.*

S$_3$ Anterior plate trapezoidal in outline, rounded at each angle, about 0.6 times as long as wide, proximal width twice the distal one; a tuft of long hairs absent in front of middle of posterior ridge of the last thoracic sternite ....*Parapenaeopsis hardwickii.*

S$_4$ Anterior plate semicircular in outline; a tuft of long hairs exists a little in front of middle of posterior ridge of the rearmost thoracic sternite ....*Parapenaeopsis sculptilis.*

R$_2$ Anterior plate rather small, its posterior margin does not extend to middle of the last thoracic sternite

U$_1$ Thelycum consists of three median plates which come into contact with one another, and are subpentagonal in their general outline; anterior plate subtriangular in outline, rounded at apex, furnished on posterior border with one median and two lateral lobes (median one of which about thrice as wide as lateral ones, considerably convex on posterior border, lateral ones directed postero-laterally, almost straight on antero-lateral edge, somewhat convex on posterior border, pointed at apex), with a narrow depression in posterior half of ventral surface; intermediate plate subtrapezoidal in outline, narrowed posteriorly by about two-thirds, provided with a median depression which is very narrow in anterior half and continuous to that of anterior plate, but rather broad in posterior half, and has a lunate swelling in each antero-lateral region; posterior plate somewhat v-shaped in outline, rounded on outer border, considerably depressed medially ....*Parapenaeus fissurus.*

U$_2$ Thelycum composed of six elevations: one anterior, three intermediate, and two posterior ones; anterior elevation invertedly cardiform in outline, narrowly rounded on anterior rim, somewhat emarginate on posterior border, a little convex on ventral surface, about as long as wide; intermediate three elevations much smaller than anterior one, median one somewhat narrowed posteriorly, about 1.1 times as long as wide measured in the widest region, slightly convex on anterior rim, rounded at each antero-lateral and posterior angle, and exceeded by all other elevations, lateral elevations lunate in outline, convex on anterior border, almost straight on posterior margin, rounded at both inner and outer angles, located behind and between posterolateral base of anterior elevation and posteromedian base of fourth pereiopods, and directed antero-laterally; posterior ones much larger in size than intermediate ones, but considerably smaller than anterior one, placed at one-third of posterior ridge of the last thoracic sternite, about 0.6 times as long as wide measured in the broadest region, crescent in outline, a trifle concave on anterior border, strongly convex on posterior edge, and rounded at each lateral angle ....*Parapenaeus sextuberculatus.*

U$_3$ Anterior plate ovoid in outline, 1.8 times as long as wide, with a large quadrate notch at middle of posterior border; posterior plate broad, fused with posterior rim of the last thoracic sternite, triple-concave on anterior edge, ill-defined on lateral border, flattish in most part of ventral surface, but the surface medially depressed anteriorly, and has a low conical upheaval in front of middle of posterior margin .... *Parapenaeus investigatoris.*

O_2 Anterior plate broad, but longer than wide, provided with a long apical projection which is acutely pointed at tip and reaches to base of second pereiopods .... Type-N_6

V_1 Anterior plate angulated disto-laterally

W_1 Anterior plate about twice as long as wide measured in anterior widest region, and not concave on lateral border .... *Eusicyonia lancifer japonica, E. cristata.*

W_2 Anterior plate violin-shaped in outline, about three times as long as wide measured in the broadest region, remarkably concave on lateral edge, semicircularly convex on posterior border .... *Eusicyonia vitulans.*

V_2 Anterior plate not angulated disto-laterally

X_1 Anterior plate notched on lateral edges

Y_1 Anterior plate about 2.5 times as long (including apical projection) as wide measured in the notched region

Z_1 Anterior plate notched at one-fourth (including apical projection), basal part from the notch as wide as distal part from the notch .... *Eusicyonia nebulosa.*

Z_2 Anterior plate notched at one-sixth, basal part from the notch wider than distal part from the notch .... *Eusicyonia curvirostris.*

Y_2 Anterior plate four times as long as wide measured between lateral notches; posterior part from the lateral notch narrower than anterior part from the lateral notch .... *Eusicyonia inflexa.*

X_2 Anterior plate without notch on lateral borders, about 2.2 times as long (including apical projection) as wide measured in the widest region .... *Eusicyonia truncata.*

A_6 Thelycum consists of a median and a pair of lateral elevations, and usually without saccate seminal-receptacle; lateral elevations well calcified, not membranous, and do not occupy almost entire part of the last thoracic sternite .... Type-N_7

a_1 Lateral elevations form no lumen on each side of median elevation

b_1 Median elevation present anterior to lateral elevations

c_1 Median elevation less upheaved than lateral ones, made up of one median and two lateral lobes; median lobe somewhat cucumber-shaped in outline, convex on ventral surface, lateral lobes Σ'-shaped; lateral elevations c-shaped in outline, acute at anterior end, reaching somewhat behind middle of median elevation, flattish on ventral surface, posterior border touches anterior rim of posterior ridge of the last thoracic sternite *Metapenaeus affinis.*

c_2 Median elevation simple, lifted as high as lateral elevations, does not touch posterior ridge of the hindmost thoracic sternite

d_1 Posterior ridge of the last thoracic sternite without protuberance at middle

e_1 Outer border of lateral elevations remarkably raised ventrally as a laminar outgrowth; median elevation tongue-like in shape, about 1.7 times as long as wide measured in the broadest region, abruptly pointed at apex, gradually narrowed posteriorly by half; lateral elevations arc-shaped in outline, pointed at tip, reaches to posterior one-third of median elevation, posterior end of outer edge rather widely separated from each other ………*Metapenaeus monoceros.*

e_2 Outer border of lateral elevations not raised ventrally at all

f_1 Median elevation larger than lateral ones

g_1 Median elevation broad, about 1.2 times as long as wide measured in the widest region, mucronate at apex, considerably indent on outer edge, rounded on antero-lateral border, flattish on ventral surface; lateral elevations L-shaped in outline, separated from each other, but come into contact with median elevation, narrowly rounded at anterior end, and reach to middle of median elevation ………*Metapenaeus brevicornis.*

g_2 Median elevation narrow, about 2.5 times as long as wide measured in the broadest region, rounded on both anterior and posterior borders, more or less concave on each lateral border, lateral elevations narrower than median one, somewhat arcuate with convex margin outward, anteriorly exceeded by median elevation, but posteriorly surmount posterior edge of median elevation ………*Atypopenaeus compressipes.*

f_2 Median elevation as large as lateral ones, ovoid in outline, ca. 1.4 times as long as wide, flattish on ventral surface; lateral elevations closely resemble median one in general configuration, placed behind postero-lateral border of median elevation, separated from each other, directed antero-laterally ………*Metapenaeus lysianassa.*

f_3 Median elevation much smaller than lateral ones, somewhat less than twice as long as wide measured in the widest region, abruptly pointed at apex, a little concave on each lateral edge; lateral elevations subrectangular in outline, but somewhat widened posteriorly, a little longer than wide measured in the broadest region, rounded at each angle, provided on ventral surface with a carina running from antero-median corner to postero-lateral one ………*Metapenaeus spinulatus.*

d_2 Posterior ridge of the last thoracic sternite has a protuberance at middle

h_1 Median elevation much longer than wide, about four times as long as wide measured in the broadest region, rounded on both anterior and posterior edges, concave on each lateral border, posterior end reaches to about middle of the hindmost thoracic sternite; lateral elevations longer than wide, thrice as long as wide measured in the widest region, anteriorly reaching near posterior base of fourth pereiopods, and posteriorly extending near posterior ridge of the last thoracic sternite, straight on inner border, considerably convex on outer rim, minutely pointed at antero-median angle, and suddenly curves inward at posterior end which is sharply pointed; protuberance set at middle of posterior edge of the rearmost thoracic sternite acuminate at tip ………*Trachypenaeopsis richtersii.*

h_2 Median elevation cardiform in outline, slightly wider than long, does not extend posteriorly beyond posterior base of fourth legs; lateral elevations rather broad, somewhat laminar, leaf-shaped in outline, rather strongly concave on ventral surface, raised ventrolaterally, semicircularly rounded on outer border, anterior rim attains posterior rim of median elevation, posterior one reaches near posterior ridge of the rearmost thoracic sternite; protuberance attached to posterior ridge of the last thoracic sternite fig-shaped in outline .... *Penaeopsis rectactus.*

b_2 Median elevation absent anterior to lateral elevations; lateral elevations located at about middle of the last thoracic sternite, directed antero-laterally, arc-shaped in outline, posterior edge remarkably elevated ventrally; median elevation inserted in front of pasterior ridge of the last thoracic sternite, compressed, much longer than wide, bluntly pointed at apex. (Coxal plate of fourth pereiopods prominent) .... *Metapenaeus intermedius.*

a_2 Lateral elevations form a lumen on each side of median elevation; median elevation racket-shaped in outline, twice as long as wide measured in the broadest region, flattish on ventral surface; lateral elevations somewhat c-shaped, anterior half remarkably lifted ventro-medially as a laminar lobe which is rounded at apex, and almost comes into contact with lateral rim of median elevation, anterior border reaches to posterior base of fourth pereiopods, posterior border touches anterior rim of posterior ridge of the last thoracic sternite; posterior ridge of the hindmost thoracic sternite has no projection .... *Metapenaeus joyneri.*

A_7 Thelycum has a large cylindrical or saccate seminal receptacle on the last thoracic sternite, and a median elevation in front of the receptacle; seminal receptacle occupies almost entire part of the last thoracic sternite .... Type-N_8.

i_1 Seminal receptacle not cylindrical, made up of two lateral lobes which are lamellar, ill-calcified, and meet along median line or medially somewhat overlap one another

j_1 Anterior protuberancc of the elevation set in front of seminal receptacle is as long as wide or wider than long, rounded or mucronate at apex; seminal receptacle circular in outline, as long as wide or somewhat longer than wide

k_1 Each lateral lobe of seminal receptacle simply flattish on ventral surface

.... *Penaeus monodon*
Penaeus bubulus
Penaeus merguiensis
Penaeus esculentus
Penaeus brevirostris

k_2 Each lateral lobe of seminal receptacle provided along anterior three-fifths of outer edge with an ill-defined narrow swelling which is rounded on posterior border .... *Penaeus orientalis.*

j_2 Anterior protuberance of the elevation lying in front of seminal receptacle ogival in outline, about twice as long as wide; seminal receptacle assumes the outline of an inverted dome, as long as wide .... *Penaeus longistylus.*

j_3 Anterior protuberance of the elevation placed in front of seminal receptacle subrhombic, about twice as long as wide measured in the widest region, acute at apex; seminal receptacle subrectangular in outline, as long as wide measured at base, somewhat narrowed anteriorly .... *Penaeus teraoi.*

J_4 Anterior protuberance of the elevation situated in front of seminal receptacle bifurcate at apex; seminal receptale much shorter than wide measured at base, somewhat widened posteriorly .... *Penaeus latisulcatus.*

i_2 Seminal receptacle cylindrical, somewhat depressed, as long as wide (wider than long in young form), with elliptical opening forward .... *Penaeus japonicus.*

L. APPENDIX MASCULINA

a. General feature

Appendix masculina of penaeids furnishes a character important for taxonomic and phylogenetical studies of the animals of the present family. Some observations on the organ were done by BATE (1888), PESTA (1918), and BURKENROAD (1934 and '36), since BOAS (CALMAMM, 1909, p. 274). However no scrutiny has been undertaken on it from viewpoint of comparative morphology dealing with a large number of specimens. Accordingly much is left to be desired in this line of research. The appendage in question is well calcified, and varies in general feature from species to species in most cases. But it is essentially composed of two pieces, proximal and distal. The proximal piece is a broad swelling, firmly attached to antero-median surface of the second pleonic endopodite, usually much longer than wide, sometimes provided with tumid outgrowths and processes. The distal piece is more variable in feature than the proximal one, much smaller than the other in size, remarkably thickened in most cases, unsegmented, rarely two-jointed in Penaeinae and Eusicyoninae, but usually much larger than the proximal piece, scale-like, and consists of two scales: inner and outer, in Aristaeinae and Solenocerinae.

With regard to the general configuration of the stractures, the following ten divisions which are symbolized, Types O_1–O_{10}, may be recognized.

Type–O_1: Proximal piece is usually smooth, somewhat convex on outer surface, and has no structures except hairs. Distal piece spatulate getting gradually thinner toward apex, rounded at apex, somewhat concavo-conex with convex surface outward, usually longer than wide, provided with setae along margins (Fig. 58).

This type is represented by all species of *Penaeus*, and *Penaeopsis rectactus* as well as *Miyadiella pedunculata*. Notably enough, the distal piece of Pacific American species, *Penaeus vannamei* and *P. stylirostris* is remarkably elongated, somewhat more than twice as long as wide (Fig. 58, *M* and *N*). The appendage in question of *Miyadiella pedunculata* closely resembles that of young form of the following species of *Penaeus* in general feature, namely, *P. monodon*, *P. bubulus*, *P. latisulcatus*, and *P. japonicus* (Fig. 58, *O*). Moreover, the appendage of *Penaeopsis rectactus* is set apart in feature from typical form of this type in having the proximal piece with a longitudinal elevation on the outer surface and the distal piece much wider than long (Fig. 58, *P*).

Type–O_2: proximal piece bare, about 1.5 times as long as wide measured in the widest region, greatly narrowed distally, and longitudinally swollen along antero-median border. Distal piece subquardrate in outline, somewhat more than half the length of proximal piece, smooth, and considerably convex on outer surface, with wavy distal margin, and armed with many short pointed setae (Fig. 59). Only *Trachypenaeus* belongs to the present type.

Type–O_3: proximal piece slender, about thrice as long as wide, markedly swollen along antero-median border and on posterior surface along outer border. Distal piece horse-hoof-shaped, one-third the length

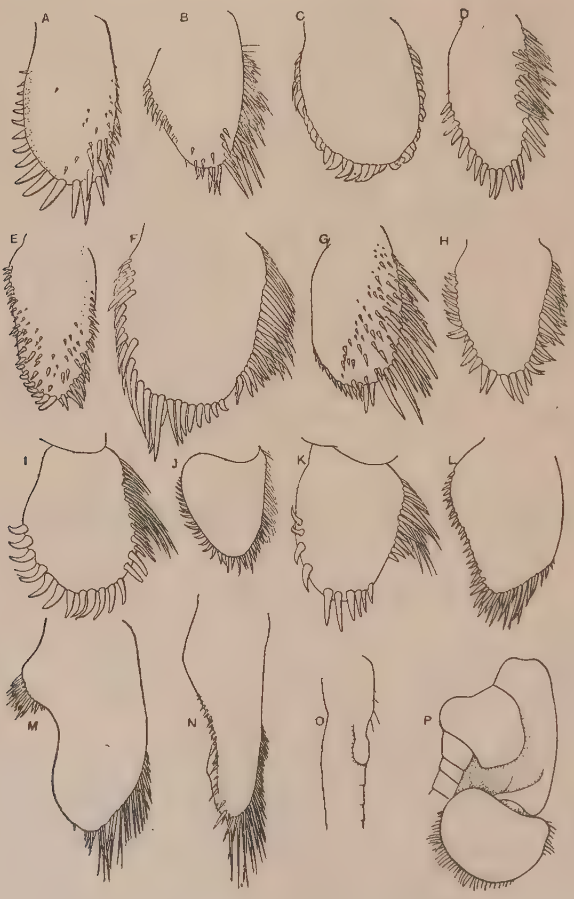

Fig. 58. Distal piece of appendix masculina (*A–N*) and appendix masculina (*O* and *P*). *A*, *Penaeus japonicus*, 116 mm in body-length (33.5 mm in carapace-length), ×20; *B*, *Penaeus latisulcatus*, 147 (40), ×16; *C*, *Penaeus monodon*, 120 (30), ×16; *D*, *Penaeus bubulus*, 129 (36), ×16; *E*, *Penaeus longistylus*, 149 (41), ×16; *F*, *Penaeus orientalis*, 152 (45), ×12; *G*, *Penaeus teraoi*, 134 (38), ×20; *H*, *Penaeus penicillatus*, 121 (31), ×20; *I*, *Penaeus esculentus*, 129 (33.2) ×16; *J*, *Penaeus indicus*, 120 (28.5), ×12; *K*, *Penaeus merguiensis*, 74 (19.8), ×28; *L*, *Penaeus brevirostris*, 128 (34), ×12; *M*, *Penaeus vannamei*, 138 (35.5), ×8.4; *N*. *Penaeus stylirostris*, 147 (41), ×8.4; *O*, *Miyadiella pedunculata*, 20 (6.3) ×40; *P*, *Penaeopsis rectactus*, 92 (21.5), ×16.

of proximal piece, somewhat indent on distal surface, furnished with ill-calcified tongue-like flap near center of distal surface (Fig. 60).

Eusicyonia lancifer japonica, *E. cristata*, and *E. curvirostris* belong to this type. Moreover, *Sicyonia sculpta* of BATE (*op. cit.*, p. 294, p. 43, fig. 3) and *Sicyonia sculpta* of PESTA (*op. cit.*, p. 47, figs. 10–12) may be perhaps included in this group.

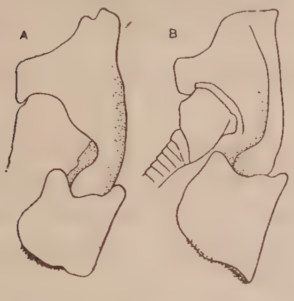

Fig. 59. Appendix masculina of Type–O_2. *A*, *Trachypenaeus curvirostris*, 79 mm in body-length (23 mm in carapace-length), ×6; *B*, *T. asper*, 61 (16), ×12.8.

Type–O_4: proximal piece tumid along antero-median edge as in Type–O_2, and provided with an embossed protuberance, bearing rounded distal border at middle and a little nearer to proximal end than to distal one of anterior surface. Distal piece about half as long as proximal piece, closely resembles in general feature that of Type–O_3, but wavy on distal surface, and without tongue-like flap (Fig. 61).

This type is exemplified by all *Parapenaeus* only.

Type–O_5: similar to type–O_4 in general aspect. Proximal piece a little longer than wide, swollen along antero-median border, and has no prominence on anterior surface. Distal piece glabrous, not segmented, a trifle shorter than proximal piece, proximally slender, suddenly thickened assuming the outline of a horse-hoof, furnished with a deep hollow on distal surface (Fig. 62).

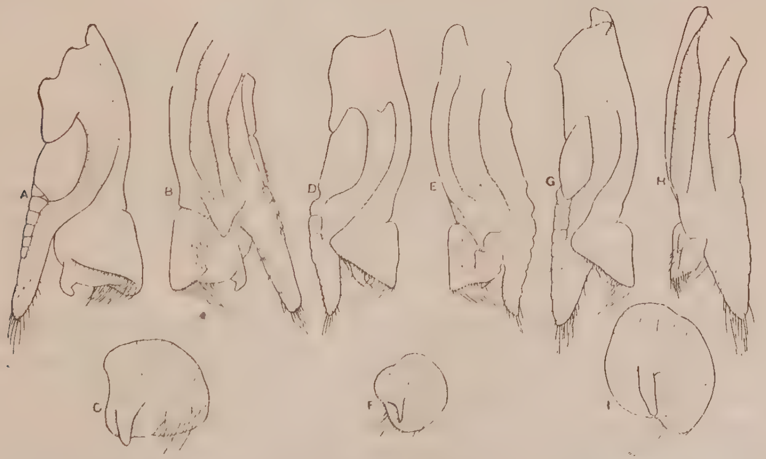

Fig. 60. Anterior (*A*, *D*, and *G*), posterior (*B*, *E*, and *H*), and apical (*C*, *F*, and *I*) aspects of appendix masculina of *Eusicyonia*. *A–C*, *E. lancifer japonica*, 47 mm in body-length (15 mm in carapace-length); *D–F*, *E. cristata*, 43 (12); *G–I*, *E. curvirostris*, 57.4 (14.3). *A* and *B*, ×12; *C–H*, ×16; *I*, × 28.

All *Metapenaeus* belong to this type.

Type–O_6: proximal piece markedly thickened along median border, and has an auriculate plate, with rounded apex directed inward at distal outer end. Distal piece slender, cup-shaped, twice or somewhat more than twice as long as wide measured near proximal margin, about one-seventh the length of proximal piece, gradually somewhat widened distally, circular and considerably concave on distal surface (Fig. 63, *G* and *H*).

Represented by *Parapenaeopsis hardwikii* and *Parapenaeopsis cultrirostris.*

Type–O_7: the organ of this type not jointed, with no projections on anterior surface, greatly thickened along inner border, considerably arcuate on median edge. The thickened portion rather suddenly increased in size at apex, truncate at distal end, circular or semicircular and somewhat concave on distal surface (Fig. 64).

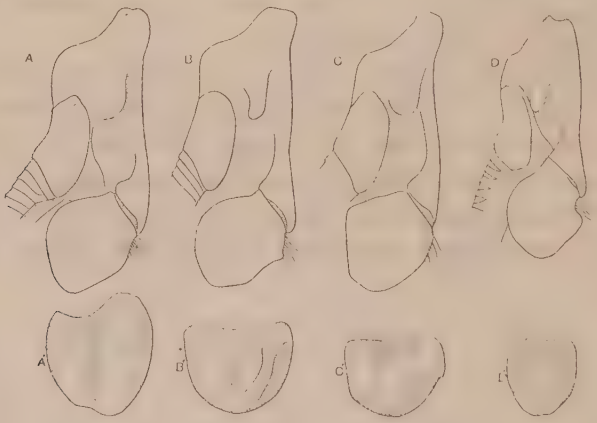

Fig. 61. Anterior view (*A–D*) of appendix masculina and apical one (*A′–D′*) of distal piece of the same appendage of *Parapenaeus. A* and *A′ P. sextuberculatus,* 85 mm in body-length (21.5 mm in carapace-length); *B* and *B′*, *P. fissurus,* 74 (19); *C* and *C′*, *P. lanceolatus,* 67.1 (17); *D* and *D′*, *P. investigatoris,* 63 (14.9) *A–C,* ×12; *D* and *A′–D′*, ×16.

All species of *Metapenaeopsis* and *Atypopenaeus compressipes* are embraced in the present type. It may be noticed that the organ of *A. compressipes* is more conspicuously expanded at apex than that of *Metapenaeopsis.*

Type–O_8: proximal piece thickened along median border as in the case with Types, O_3–O_7, almost straight on median border, provided with no protuberance on anterior surface. Distal piece two-segmented, directed somewhat outward, greatly shorter than proximal piece; proximal segment decidedly shorter than wide; distal segment horse-hoof-shaped like the distal piece of Type–O_3, much larger than proximal segment, sometimes furnished with a tongue-like flap on distal surface (Fig. 63, *A–F*).

This type is peculiar to *Parapenaeopsis tenellus*, *P. cornutus*, and *P. hungerffordi*. *Parapenaeopsis balli* of BURKENROAD (1934b, p. 64,) fig. 18) is also ascribable to this type.

Type–O_9: proximal piece similar to that of Type–O_1, slightly convex on anterior surface. Distal piece consists of two scales: inner

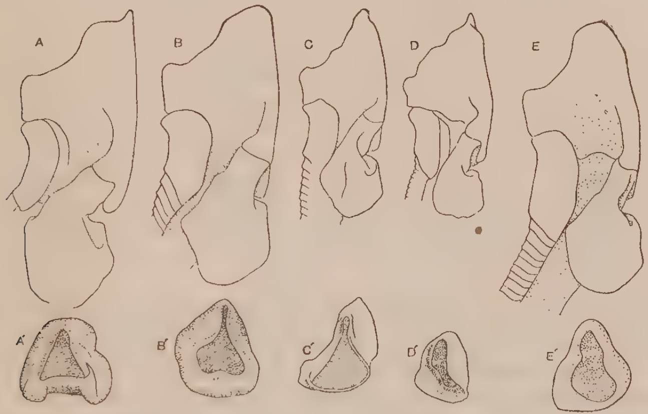

Fig. 62. Anterior aspect (*A–E*) of appendix masculina, and apical one (*A′–E′*) of distal piece of the same appendage of *Metapenaeus*. *A* and *A′*. *M. joyneri*, 102 mm in body-length (25 mm in carapace-length); *B* and *B′*, *M. tenuipes*, 76 (18.5); *C* and *C′*, *M. affinis*, 67.5 (15.5); *D* and *D′*, *M. monoceros*, 108 (29.8); *E* and *E′*, *M. intermedius*, 142 (40). *A* and *A′*, ×8.4; *B*, *B′*, and *E*, ×12.

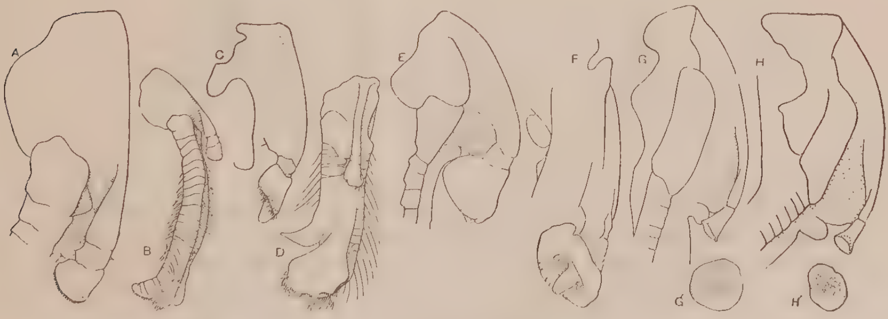

Fig. 63. Anterior aspect of appendix masculina (*A*, *C*, and *E–H*) and second pleonic endopodite with appendix masculina (*B* and *D*). *A* and *B*, *Parapenaeopsis cornutus*, 83 mm in body-length (24 mm in carapace-length); *C* and *D* *Parapenaopsis fungerfordi*, 61 (17); *E*, *Parapenaeopsis tenellus*, 38 (10.1); *F*, *P. tenellus*, 21 (6); *G* and *G′*, *Parapenaeopsis hardwickii*, 58 (15.5); *H* and *H′*, *Parapenaeopsis cultrirostris*, 67 (17). *A* and *H*, ×12; *B*, 4.8; *C*, ×16; *D*, ×8.4; *E*, *F* and *H′*, ×28; *G*, ×20; *G′*, ×40.

smaller and outer larger. Inner scale ill-calcified, thin, flattish on both inner and outer surface, entirely hidden by outer scale. Outer scale well calcified, somewhat convex on inner surface and concave on the other (Fig. 65).

Aristacomorpha foliacea and *Aristaeus virilis* are involved in the present type.

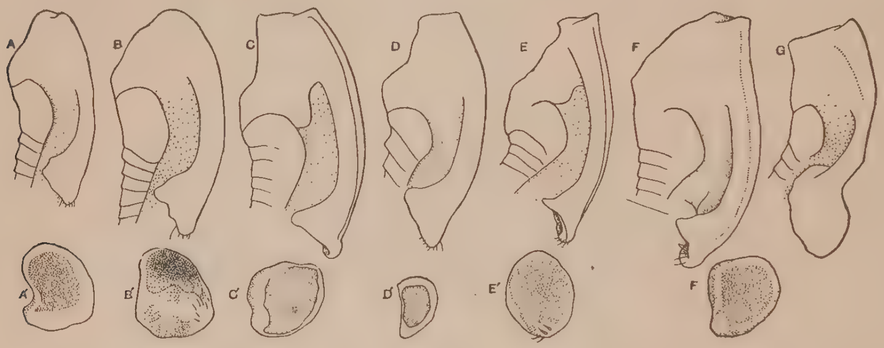

Fig. 64. Anterior (*A*–*G*) and apical (*A'*–*F'*) aspects of appendix masculina referable to Type–O_8. *A* and *A'*; *Metapenaeopsis barbatus*, 66 mm in body-length (15 mm in carapace-length); *B* and *B'*, *M. acclivis*, 58.9 (13.3); *C* and *C'*, *M. durus*, 77 (17); *D* and *D'*, *M. dalei*, 70 (17.5); *E* and *E'*, *M. coniger*, 58 (12); *F* and *F'*, *M. lamellatus*, 66.3 (14.9); *G*, *Atypopenaeus compressipes*, 28 (8). *A* and *C*, ×12; *A'* and *F*, ×8.4; *B*, *D*, *D'*, *E*, and *E'*, ×16; *B'*, ×28; *G*, ×40.

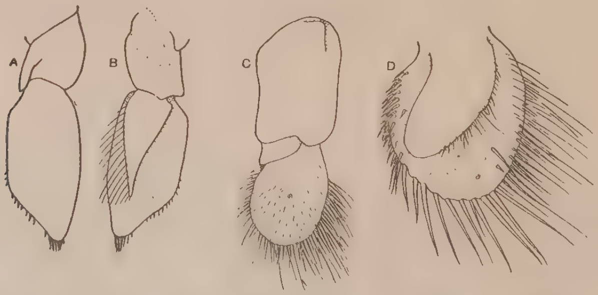

Fig. 65. Anterior (*A* and *C*) and posterior (*B* and *D*) aspects of appendix masculina referable to Type-O_9. *A* and *B*, *Aristaeus virilis*, 148 mm in body-length (47 mm in carapace-length), ×4.8; *C*, *Aristaeomorpha foliacea*, 127 (41), ×8.4; *D*, same as in *C*, ×16.

Type–O_{10}: proximal piece well calcified, provided with upheavals on anterior and posterior surfaces besides a prominent spur-like projection directed obliquely downward or almost downward on postero-lateral surface. Distal piece mad up of two, inner and outer, pod-like scales. Inner scale much longer than proximal piece and usually much larger than spur-like projection of proximal piece, attached to proximal piece, pointing infero-laterally or almost inferiorly, with convex surface inward, and rounded at apex. Outer scale somewhat smaller than, or subequal to, inner scale in size, but usually longer than spur-like projection of proximal piece, directed infero-laterally or almost inferiorly as in inner scale, rounded on distal border (Fig. 66).

All the species included to the genera, *Solenocera* and *Hymenopenaeus*, and *parahaliporus sibogae* are referable to the present type. *Hymenopenaeus debilis Smith* and *H. aphoticus* BURKENROAD (BURKENRORD, 1936, pp. 111–118, figs 64 and 65) may possibly belong to this type.

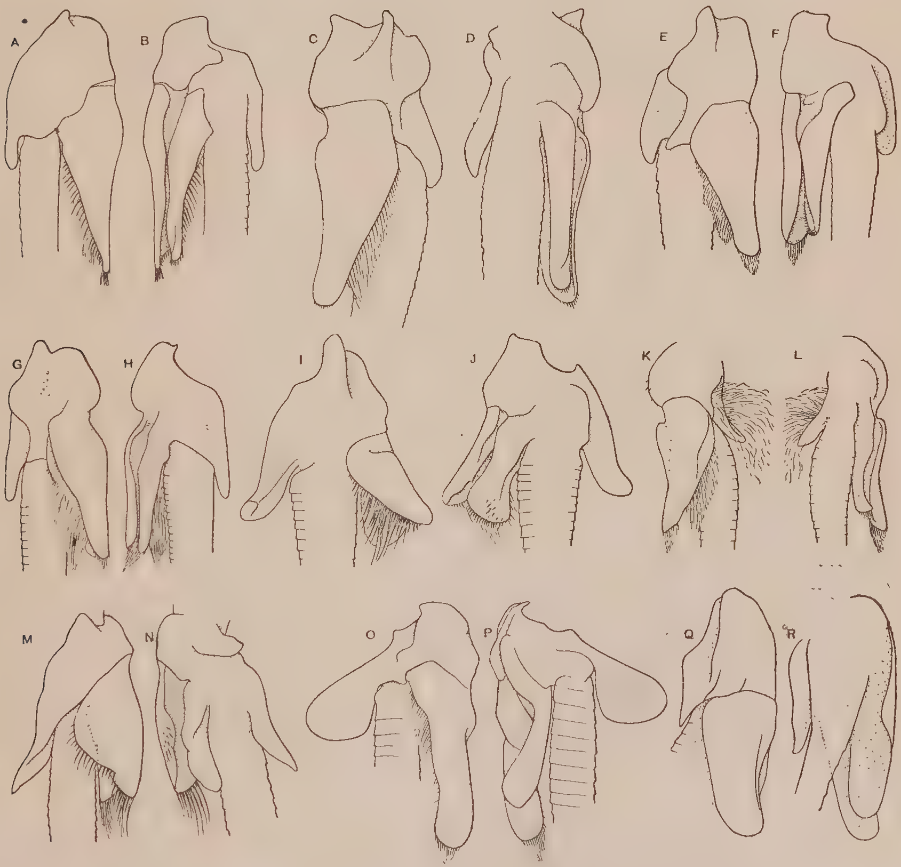

Fig. 66. Posterior (*A*, *D*, *E*, *G*, *I*, *K*, *M*, *O*, and *Q*) and anterior (*B*, *C*, *F*, *H*, *J*, *L*, *N*, *P*, and *R*) aspects of appendix masculina referable to Type-O_{10}. *A* and *B*, *Solenocera faxoni*, 50 mm in body-length (14.8 mm in carapace-length); *C* and *D*, *Solenocera subnuda*, 61.5 (18.2); *E* and *F*, *Solenocera depressa*, 58 (17); *G* and *H*, *Solenocera prominentis*, 81 (22.1); *I* and *J*, *Solenocera brevipes*, 46 (13); *K* and *L*, *Solenocera pectinulata*, ca. 38 (10); *M* and *N*, *Hymenopenaeus aequalis*, (14.5); *O* and *P*, *Hymenopenaeus lucassi*, 103 (19.5); *Q* and *R*, *Parahaliporus sibogae*, 115 (29.5). *A*, *B*, *E*, and *F*, ×12; *C*, *D*, *I-N*, and *R*, ×16; *G*, and *H*, ×6; *O-Q*, ×8.4.

b. Metamorphosis of the appendix masculina of some species

No investigation has been done, so far as the writer's knowledge is concerned, on metamorphosis of appendix masculina of any species referable to this family. In the course of the present study, the writer has been able to follow rather completely the serial changes of this organ in such specis as *Penaeus latisulcatus*, *P. monodon*, *P. teraoi* *P. bubulus*, *Trachypenaeus curvirostris*, *Metapenaeopsis barbatus*, *Aristaeomorpha foliacea* and *Aristaeus virilis*. The first four belong to Type-O_1, the fifth to Type-O_2, the sixth to Type-O_7, and the last two to Type-O_{10}. Besides these, some observations of the same subject of the following species of *Metapenaeus*, *M. affinis*, *M. joyneri*, and *M. monoceros* have been made on incomplete series of material which are deficient in early stages.

1. Description

Penaeus latisulcatus. In a young male, 35.5 mm long, the distal piece is 0.08 mm in length, spatulate in outline, rounded on distal margin, a little longer than wide (Fig. 67, *A*). At the time the animal attains a length of 48 mm, the distal piece closely resembles that of the preceding stage, 35.5 mm long, measures about 0.2 mm in length, and is 1.3 times as long as wide, having three setae in distal half of outer border and a seta on apical one (Fig. 67, *B*). As shown in Fig. 67, *C*, the distal piece amounts to 0.5 mm in length and 0.29 mm in width measured in the broadest region, gradually narrowed distad from about the middle, rounded at apex, and provided with many pointed setae in distal one-third of inner and in distal half of outer borders. In a specimen, 93 mm long, the distal piece almost resembles that of adult form in general feature (Fig. 67, *D*). It is about 0.7 mm in length, about 0.6 times longer than wide, narrowed in distal half as the outer border considerably turns inward, rounded at apex, furnished with rather thickly set setae along other borders except proximal one-third of the outer one. The setae set along outer border are shorter than those of inner one.

Comparison: As exhibited in Fig. 67, *E–Q*, the metamorphosis of the appendage in question of *Penaeus monodon*, *P. penicillatus*, *P. japonicus* and *P. bubulus* is very similar to that of *P. latisulcatus* in general respects. But the facts given in the following lines are worthy of mentioning. Anlage of the distal piece of *P. monodon* makes its appearance when the animal measures 34 mm in body-length. It is about 0.2 mm in length, crescent in outline, with strongly convex distal border, and about twice as long as wide. The distal piece is still bare in *P. monodon*, 62 mm long, in *P. japonicus*, 33.5 mm long, and in *P. bubulus*, 61 mm long. It is, however, found bearing setae along borders in *P. monodon*, 78 mm long, in *P. penicillatus*, 67 mm long, in *P. japonicus*, 67.5 mm long, and in *P. bubulus*, 70.5 mm long.

Trachypenaeus curvirostris. When the animal attains a length of 20 mm, the apparatus in question is well differentiated already, closely resembling that of *Miyadiella pedunculata* in general feature, and measuring 0.44 mm in length. Proximal piece somewhat convex on inner surface, a little narrowed distally. Distal piece spatulate, slightly decreasing in width toward rounded apex, without setae along distal border, one and half times as long as wide measured in broadest region, about half the length of proximal piece (Fig. 68, *K*).

Stage, 25 mm long: the appendage is somewhat modified in general feature from that of the preceding stage, 20 mm long (Fig. 68, *L*). Distal piece furnised with proximo-lateral angles rather defined, not nar-

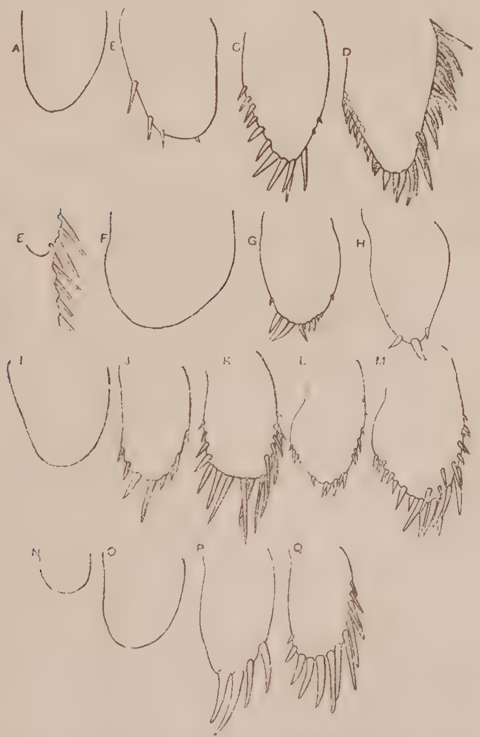

Fig. 67. Metamorphosis of distal piece of appendix masculina of *Penaeus latisulcatus* (*A-D*), *Penaeus monodon* (*E-G*), *Penaeus penicillatus* (*H*), *Penaeus japonicus* (*I-K*), *Penaeus teraoi* (*L* and *M*), and *Penaeus bubulus* (*N-Q*). *A*, 35.5 mm in body-length (10 mm in carapace-length), ×200; *B*, 48 (13.5), ×100; *C*, 67 (19), ×50: *D*, 93 (25), ×35; *E*, 34 (10), ×75; *F*, 62 (16.5), ×100; *G*, 78 (20), ×35; *H*, 67 (17.5), ×50; *I*, 33.5 (10), ×200; *J*, 67.5 (20), ×50; *K*, 87.5 (27), ×35; *L*, 87 (24), ×35; *M*, 100 (27.5), ×35; *N*, 52 (15.5), ×100; *O*, 61 (17.4), ×100; *P*, 70.5 (21.5), × 50; *Q*, 97 (27), ×25.

rowed distally, flattish on inner surface, but still rounded at apex, bearing five short setae, ca. 0.2 mm in length, somewhat less than twice as long as wide.

Stage, 34 mm in body-length: proximal piece ca. 0.56 mm in length. Distal piece subrectangular in outline with corners rounded, about 0.3 mm in length, 1.3 times as long as wide, still flattish on inner surface,

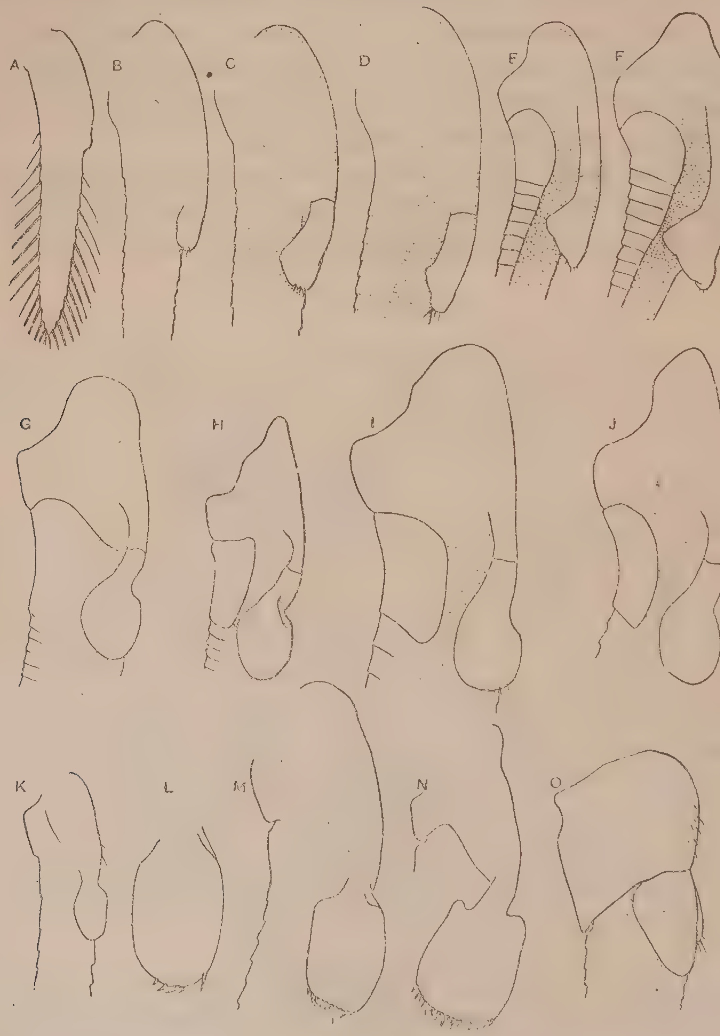

Fig. 68. Metamorphosis of appendix masculina of *Metapenaeopsis barbatus* (*A–F*), *Metapenaeus joyneri* (*I* and *J*), and *Trachypenaeus curvirostris* (*K–N*), and appendix masculina of young form of *Metapenaeus monoceros* (*G*), *Metapenaeus affinis* (*H*), and *Parahaliporus sibogae* (*O*). *A*, 19.5 mm in body-length, ×55; *B*, 26 mm, ×55; *C*, 32 mm, ×50; *D*, 37 mm, ×50; *E*, 51.5 mm, ×25; *F*, 70 mm, ×15; *G*, 62 mm in body-length (16.5 mm in carapace-length), ×7.5; *H*, 45.5 (11), ×25; *I*, 40 (11), ×50; *J*, 55 (13.5), ×25; *K*, 20 (6), ×50; *L*, 25, ×100; *M*, 34 (9), ×50; *N*, 37 (9.5), ×35; *O*, 60 (15.5), 35.

provided with about ten short setae along distal border (Fig. 68, *M*).

Stage, 37 mm in body-length: proximal piece measures about 0.67 mm in length, turns obliquely outward in distal one-fourth, and somewhat swollen along inner border. Distal piece about 0.44 mm in length, 1.2 times as long as wide, a little widened toward apex, more or less convex on inner surface, somewhat convex on apical edge which is furnished with 17 rather sparsely sat short setae (Fig. 68, *N*).

Adult form of this appendage is reached at the time the animal attains a length of about 50 mm.

Metapenaeus joyneri. A specimen, 40 mm long, has well differentiated appendix masculina (Fig. 68, *I*). Proximal piece 0.57 mm in length, considerably swollen along inner border in distal one-third. Distal piece about 0.34 mm in length, similar to that of *Miyadiella peduncularta*, and that of early stage, 20 mm long, of *Trachypenaeus curvirostris* in feature, rounded at distal margin, twice as long as wide.

When the animal measures about 55 mm in body-length exhibits no remarkable modification in general aspect comparing with that of the preceding stage. Proximal piece 1.14 mm in length. Distal one 0.64 mm in length, with apical hollow not differentiated yet (Fig. 68. *J*).

Metapenaeus monoceros and Metapenaeus affinis. The appendage of *M. monoceros*, 62 mm long, closely resembles that of *M. joyneri*, 40 mm long, in general configuration. Proximal piece about 3 mm, distal one 2 mm in length (Fig. 68, *G*).

The appendage of *M. affinis*, 45.5 mm in body-length is very similar to that of *M. joyneri*, 40 mm long. and *M. monoceros*, 62 mm long in general aspect. Proximal piece 0.84 mm. Distal one measures a length of 0.6 mm bearing no hollow on apical surface as in that of *M. joyneri*, 55 mm long, and that of *M. monoceros*, 62 mm long (Fig. 68, *H*).

Metapenaeopsis barbatus. In a male, 19.5 mm in body-length, appendix masculina makes its appearance as a minute swelling at about two-fifths of antero-inner border of second pleonic endopodite (Fig. 68, *A*).

At a stage, 26 mm long, proximal piece still hardly differentiated. Articulation between proximal and distal pieces ill-defined yet. Distal piece thumb-like, about 0.1 mm in length, thrice as long as wide, half the length of proximal piece, rounded at apex bearing three setae (Fig. 68, *B*).

Stage, 32 mm in body-length: proximal piece 0.48 mm in length. Articulation between two component pieces well defined. Distal piece about 0.25 mm in length, gradually thickened distally, truncate at distal end, directed somewhat infero-laterally in distal half, furnished with three setae on apical border (Fig. 68, *C*).

In a little advanced stage, 37 mm in body-length, proximal piece measures 0.56 mm in length, and shows no change in feature compared with that of preceding stage, 32 mm long. Articulation between both proximal and distal pieces remains well defined yet. Distal piece 0.27 mm in length, a trifle slenderer than that of the stage, 32 mm long, somewhat less than thrice as long as wide measured in the widest region (Fig. 68, *D*).

Stage, 51.5 mm in body-length, the appendage almost assumes its adult form (Fig. 68, *E*). Proximal piece 0.83 mm in length, considerably swollen along inner border. Articulation between proximal and distal pieces still persists faintly. Distal piece measures 0.5 mm in length.

In an adult form, 70 mm in body-length, the appendage about 2.5 mm in total length. Articulation found between the component pieces not recognizable (Fig. 68, *F*).

Aristaeomorpha foliacea. In a specimen, 69 mm in body-length, appendix masculina is considerably developed already (Fig. 69, *A*), Distal piece still consists of a single scale, subrectangular in outline, measuring 0.4 mm in length, about twice as long as wide, rounded on

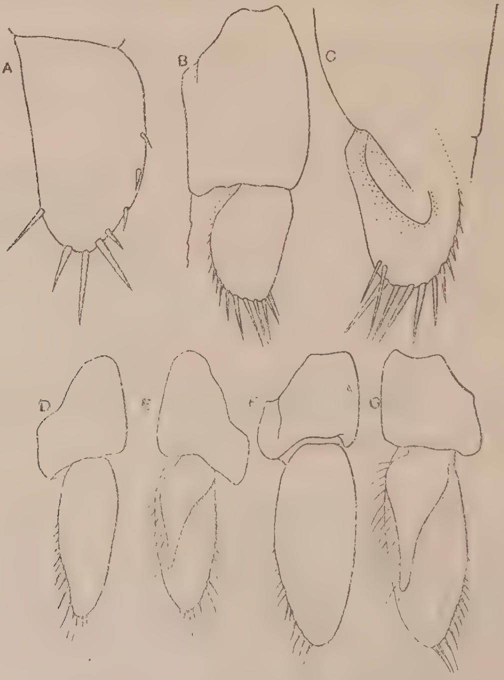

Fig. 69. Metamorphosis of appendix masculina of *Aristaeomorpha foliacea* (*A*-*C*) and *Aristaeus virilis* (*D*-*G*). *A*, *B*, *D*, and *F*, inner aspect; *C*, *E*, and *G*, outer aspect. *A*, 69 mm in body-length (21 mm in carapace-length), *B* and *C*, 81 (26); *D*, and *E*, 85 (20); *F* and *G*, 94 (28). *A*, ×75; *B*, ×25; *C*, ×35; *D* and *E*, ×20; *F*, and *G*, ×15.

distal margin, furnished with setae on distal and outer borders.

On reaching a stage, 81 mm long, distal outer piece makes its appearance, so that the distal piece is composed of two scales (Fig. 69, *C*). Inner scale a little convex on inner surface, slightly widened distally with almost straight inner, convex outer and distal borders, 0.6 mm in length, 0.4 mm in breadth measured in the widest region, fringed with many setae along outer and distal edges; setae increased in number compared with those of the preceding stage, 69 mm long, those of outer edge successively increase in length toward apex. Outer scale yet very vestigial, lamellar, tongue-like, rounded on distal border, measuring about 0.4 mm in length, three times as long as wide, directed obliquely outward, devoid of setae.

Appendix masculina of an adult form, 127 mm in body-length, measures about 3.6 mm in total length (Fig. 65, *C* and *D*). Proximal piece subrectangular in outline, 1.5 times as long as wide. Distal piece becomes much developed; inner scale ovoid in outline, somewhat shorter than proximal piece, 1.3 times as long as wide, concavo-convex, with convex surface inward, clad with rather thickly set setae on inner surface and all margins; outer scale tongue-like, somewhat shorter than inner scale and about half the width of inner one, rounded at apex, twice as long as wide, furnished with short setae along inner border.

Aristaeus virilis. At a stage, 85 mm in body-length, appendix masculina is considerably developed with distal piece composed of two scales already (Fig. 69, *D* and *E*). Proximal piece measures 0.65 mm in length. Inner scale elongatedly elliptical in outline, somewhat concavo-convex with convex surface medially, a little less than three times as long as wide, one and half times the length of proximal piece, fringed with setae in distal half of outer border and on apical one. Outer scale lamellar, rather abruptly narrowed into a point in distal two-thirds, directed infero-laterally in proximal one-third and inferiorly in the rest, entirely hidden by inner scale, about three-fourths the length of the other scale, somewhat less than thrice as long as wide, furnished with hairs along inner and outer borders.

The organ of a somewhat advanced specimen, 94 mm long, undergoes little metamorphosis in feature (Fig. 69, *F* and *G*). Proximal piece 0.9 mm in length. Inner scale still elongated avoid in outline, somewhat more than twice the length of proximal piece, about 2.4 times as long as wide, furnished in distal half of outer edge with rather sparsely set hairs which gradually increase in length toward tip. Inner scale somewhat racket-shaped in outline, about two times as long as wide measured in the broadest region, a little more than two-thirds the length of inner scale, clad with rather long subequidistantly set hairs along inner edge.

Parahaliporus sibogae. In a young specimen, 60 mm long, which is the smallest among the specimens dealt with, proximal piece subrectangular in outline, somewhat wider than long, provided with a rather low elevation bearing straight outer border and pointed distal end in distal three-fourths of outer border. Distal piece composed of inner larger and outer smaller scales already. Inner scale deltoid in outline, with rounded apex, 0.44mm in length, about 1.6 times as long as wide, 0.8 times the length of proximal piece. Outer scale very similar to inner one in feature, ca. 0.3 mm in length, two-thirds as long as proximal piece, furnished with several setae on apical margin, overlapped by inner scale in most part. (Fig. 68, *O*).

At the time the prawn measures 92 mm in body-length, the apparatus in question almost assumes its adult form in general aspect. The elevation running along outer border of proximal piece becomes more prominent. Inner scale bill-like in feature, 1.4 mm in length, about twice as long as wide, and 1.5 times the length of proximal piece. Outer scale closely resembles inner one, slightly shorter than inner one, ca. 1.3 times as long as proximal piece.

In an adult form, 115 mm in body-length, the organ shows no marked transformation comparing with that of stage, 92 mm long in general feature (Fig. 66, *Q* and *R*). Distal two scales get about twice longer than those of stage, 92 mm in body-length.

2. Remarks

As described already, the transformation of the appendix masculina of *Penaeus latisulcatus*, *P. monodon*, *P. japonicus*, and *P. bubulus* is very similar starting from a condition resembling the appendage of *Miyadiella pedunculata.* It is of great interest from standpoint of phylogeny that the appendage in question of *Aristaeomorpha foliacea*, *Trachypenaeus curvirostris*, *Metapenaeopsis barbatus*, *Metapenaeus affinis*, *M. joyneri* and *M. monoceros* is very similar in general feature to that of *Penaeus* in early stage. Remarkably enough, the distal piece of *Aristaeomorpha foliacea* consists of a single scale as is the case with that of *Penaeus* at least in specimens smaller than 69 mm long, and subseqently gets made up of two scales as a scale buds out from outer base of the primary scale. Such being the case, it appears to the writer that the type-O_1 may be taken as the most primitive among all the types, to which the appendage of all the species dealt with is referable.

The adult appendix masculina of *Metapenaeopsis barbatus* is not segmented, but it is two-segmented in such young form measuring about 26–52 mm in body-length as set forth already. Similar phenomenon is also observed in the appendage of *Metapenaeopsis acclivis.* Thus the writer is compelled to consider that unsegmented condition of adult appendix masculina of the type-O_7 is a secondary specialized one. Moreover, the spur-like projection set on outer surface of the proximal piece of the appendage ascribable to the type-O_{10} is also a secondary feature. Since the projection develops later than the distal two scales as seen in the metamorphosis of the organ of *Parahaliporus sibogae.*

c. Taxonomic and phylogenetical considerations of appendix masculina

The appendix masculina is little variable in shape within species, and not always species-specific. But, so far as the present inspection goes, it usually exhibits distinct generic or supergeneric morphological variation, and affords a criterion significant for demarkation of genus. When based on routine distinctions, the genera *Metapenaeus* and *Metapenaeopsis* (=*Penaeopsis* of most authors) are sometimes confused, and the recognition of the genera, *Parapenaeus* and *Parapenaeopsis* is of no easy task. Moreover, *Penaeopsis* is very closely allied to *Metapenaeopsis* in many important features. However, they may be well defined from each other basing on the present character. Since the appendage under the consideration is of Type-O_5 in *Metapenaeus*, of Type-O_7 in *Metapenaeopsis*, of Type-O_6 or Type-O_8 in *Parapenaeopsis*, and of Type-O_1 in *Penaeopsis.*

With respect to the general feature of the appendix masculina, two contrasted phylogenetical stems, I and II, may by naturally perceptible, arising from a common root. The stem-I is represented by eight types, O_1-O_8, and the stem-II by two types, O_9 and O_{10}. The former is characterized by having the distal piece which is a single outgrowth and usually not jointed or rarely two-jointed whilst the latter is marked by possession of the distal piece which is composed of two scales.

Type-O_1 may be taken as the most primitive among all the types as proponed elsewhere. Type-O_2 is the nearest to Type-O_1, inasmuch as the distal piece is not only rather thickened plate-like as in that of Type-O_1, but also the initial condition of the piece is of Type-O_1. Types, O_4 and O_5, very closely rsemble each other, only difference is that the latter has a deep hollow on distal surface. These two types, however, have more similarity to Type-O_3 than to Types, O_1 and O_2 bearing fist-shaped distal piece. Type-O_6 is nearer to types, O_4 and O_5, than to types, O_1-O_3. Type-O_7 considerably differs from Types, O_5 and O_6, in general aspect in adult form, as it is unsegmented. But it may be considered diverged from the same phylogenetical root with the types, O_5 and O_6, since its early condition is very similar to that of such two types as stated already. Type-O_8 is greatly deviated from all other types, which belong to the stem-I, in the respect that the distal piece is two-segmented. It must be remembered that the second segment of the distal piece is horse-hoof-shaped as in the distal piece of Type–O_3. Thus the writer is inclined to think that the Type–O_8 were given rise to from a hypothetical ancestor which is common to these types, O_3 and O_8 diverging widely and tending toward the branches represented by types, O_5 and O_6.

On the other hand, both the types, O_9 and O_{10}, from which the stem-II is branched off, are affiliated with each other in having distal piece which consists of two scales. Type–O_{10} is more specialized than Type–O_9 in possession of a spur-like projection on outer surface of the proximal piece. At any rate, these two types, in adult form, can not be put under the same category with any type belonging to stem–I. But we must look to the early condition of these types, O_9 and O_{10}, for the link which may connect the two stems, I and II. As set forth already, the distal piece of *Aristaeomorpha foliacea* is made up of a single scale which intimately resembles that of Type–O_1. Therefore it may be inferred that the stem–II is descended from a hypothetcial ancestor similar to Type–O_1.

The next key to the types may represent more cleariy the above mentioned relationship among the types, O_1–O_{10}, and it would serve for the taxonomic use.

Key to the types of appendix masculina

- A_1 Appendix masculina distally not provided with two scale-like appendages
  - B_1 Appendix masculina segmented
    - C_1 Distal piece plate-like, somewhat convex on inner surface
      - D_1 Distal piece spatulate, usually longer than wide, rounded on distal margin ....Type-O_1 (*Penaeus*, *Miyadiella* and *Penaeopsis*).
      - D_2 Distal piece subquadrate in outline ....Type-O_2 (*Trachypenaeus*)
    - C_2 Distal piece not plate-like, remarkably thickened, usually horse-hoof-shaped or fist-shaped, rarely cup-shaped
      - E_1 Distal piece not segmented
        - F_1 Appendix masculina somewhat shorter than second pleonic endopodite; distal piece horse-hoof-shaped, one-third to one-fourth as long as proximal piece, somewhat indent on distal surface, provided with a tongue-like appendage near center of distal surface ....Type-O_3 (*Eusicyonia*).
        - F_2 Appendix masculina greatly shorter than second pleonic endopodite.
          - G_1 Distal piece fist-shaped
            - H_1 Proximal piece has a protuberance with rounded distal apex on anterior surface; distal piece about half as long as proximal one, wavy on distal surface ....Type-O_4 (*Parapenaeus*)
            - H_2 Proximal piece has no protuberance on anterior surface; distal piece a little shorter than proximal one, provided with a deep hollow on distal surface ....Type-O_5 (*Metapenaeus*)

G$_2$ Distal piece cup-shaped, about twice as long as wide measured near proximal end, circular and concave on distal surface ………Type O_5

(*Parapenaeopsis hardwickii* and *P. cultrirostris*)

E$_2$ Distal piece two-segmented, horse-hoof-shaped; one-third to one-sixth the length of proximal piece ………Type-O_8

(*Parapenaeopsis tenellus, P. cornutus* and *P. hungerfordi*)

B$_2$ Appendix masculina not segmented, greatly shorter than second pleonic endopodite, markedly or strikingly thickened posteriorly, truncate at distal end, somewhat indent on distal surface ………Type-O_7

(*Metapenaeopsis* and *Atypopenaeus*)

A$_2$ Appendix masculina distally has two scale-like appendages

I$_1$ Proximal piece without prominent projection on outer surface; distal inner scale somewhat concavo-convex with convex surface inward, distal outer one flattish ………Type O_9

(*Aristaeus* and *Aristaeomorpha*)

I$_2$ Proximal piece furnished with a conspicuos projection on outer surface; distal two scales bill-like, strongly concavo-convex with convex surface inward in inner scale and convex surface outward in outer scale, rounded at apex………Type-O_{10}

(*Solenocera, Hymenopenaeus,* and *Parahaliporus*)

2. INTERNAL CHARACTERS

A. General Feature of Stomodaeal Apparatus

An anatomical research of the stomodaeal apparatus of a lower penaeid, *Cerataspis monostrosus* was made by Bonnier (Calman, 1909, pp. 279–282) so far as the writer's knowledge is concerned. However, comparative analysis of this item and application of this character to the taxonomy of Penaeidae or even any group of Macrura have never been attempted by any investigators. After an anatomical treatment of all the Penaeids at the author's disposal, it was revealed that the organ in question is well differentiated triturating structures of considerable complexity with many ossifications and so forth, and these elements found on the apparatus furnish many significant criteria for the classification and phylogeny of the family, Penaeidae.

The stomach is a specious bag, directed ventrally at an obtuse angle in posterior half. It is divided by a transverse constriction on dorsal surface into a large anterior or cardiac and a small posterior or pyloric chambers. The cardiac chamber is subrectangular in upper aspect, circular in cross-section at the middle, and continuous to oesophagus which is subquadrate in cross-section and opens to the exterior on the antero-ventral median wall. As shown in Fig. 70, the walls of the chamber are provided with the following many elements: a cardiac (*c*) and urocardiac (*uc*), a pair of pterocardiac (*pc*) and prezygocardiac (*pz*) ossicles, cardiac plates (*cp*), lateral (*lr*) and median (*mr*) ridges, and basilateral (*bl*) and lateral (*lf*) folds, of which the fourth, fifth, eighth and ninth are for the first time termed herewith. Postero-lateral walls are greatly depressed forming a sort of pouch, so that the lumen becomes rather suddenly narrow. The lining of the floor is somewhat thicker than that of other parts of this chamber, furnished with a pair of longitudinal median and lateral ridges produced internally. The median ridges are much narrower than the other ones, and gradually converge posteriorly and finally united together with each other at posterior extremity which lies below tip of the urocardiac ossicle. On the other hand, the lateral ridges are, defined from the median ridges and the cardiac plates by deep lateral and basi-lateral folds, about five times as broad as the other ones, tomentous on inner surface with rather thickly set hairs directed postero-medially. Cardio-pyloric valve lies immediately behind the posterior end of the median ridges, setose, tubercular, and usually ill-developed.

The pyloric chamber is considerably compressed, much smaller than the cardiac, subrectangular in profile, furnished with a pair of pyloric folds (*pf*), pre-ampullary (*pap*) and ampullary (*pp*) (PEARSON, 1908) or pyloric (Calman, 1909) plates, and the pyloric (*pr*) and supra-ampullary

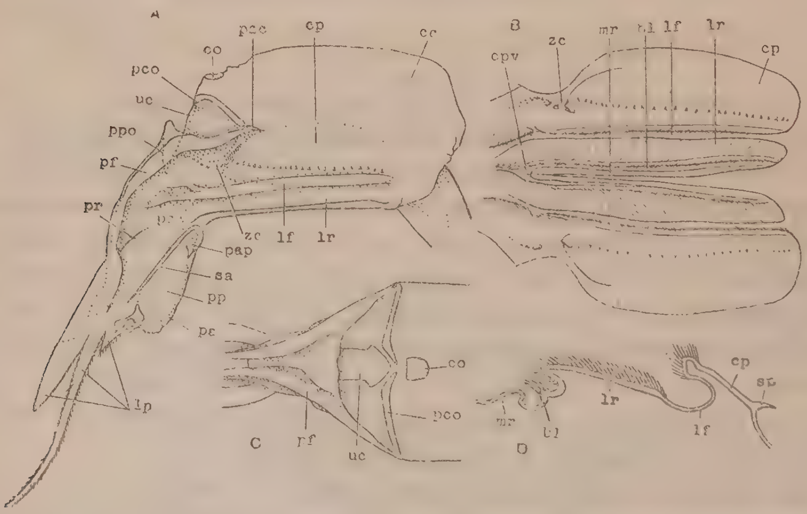

Fig. 70. *Penaeus japonicus*. *A*, lateral aspect of stomodaeal apparatus, × 2.5; *B*, inner aspect of cardiac plates, zygocardiac ossicles, and floor of cardiac chamber, ×2.5; *C*, upper aspect of posterior part of cardiac chamber and anterior part of pyloric chamber, ×2.5; *D*, cross-section of median and lateral ridges and others of cardiac chamber, ×10.5. *bl*, basi-lateral fold, *cc*, cardiac chamber; *co*, cardiac ossicle; *cp*, cardiac plate; *cpv*, cardio-pyloric valve; *lf*, lateral fold; *lp*, lappets; *lr*, lateral ridge; *mr*, median ridge; *pa*, pyloric ampulla; *pap*, pre-ampullary plate; *pc*, pyloric chamber; *pco*, ptero-cardiac ossicle; *pf*, pyloric fold; *pr*, pyloric ridge; *pp*, pyloric plate; *ppo*, prepyloric ossicle; *pzc*, prezygocardiac ossicle; *sa*, supra-ampullary ridge; *sp*, spine of cardiac plate; *uc*, uro-cardiac ossicle; *zc*, zygocardiac ossicle.

(*sa*) ridges, first two of which are newly named herein. The anterior dorsal wall corresponding to pyloric ossicle of crayfishes and crabs is more or less thickened, but still menbranous, provided with a pair of rather shallow longitudinal grooves converging posteriorly (Fig. 70, *C*). The dorso-lateral roof makes the pyloric fold, defined by a strong depression of the lateral wall, the fold runs backward starting from outer extremity of the pterocardiac ossicle. The supra-ampullary ridge is well-calcified, narrow, decreases in breadth posteriorly, commences from antero-ventral corner of the lateral wall of the pyloric chamber, and reaches to about middle of posterior edge of the lateral wall. The pyloric ridge is less prominent than the supra-ampullary ridge, slightly arcuate, laid down almost parallel to the supra-ampullary ridge, arising from about the center of the lateral wall, and attains base of the pyloric fold. The pre-ampullary plate is well-calcified, subrectangular in profile, acutely pointed at postero-inferior angle, placed immediately behind the anteroventral angle of tateral wall of the pyloric chamber lying almost parallel to the supra-ampullary ridge. The ampullary plate is suboval in outline, and occupies greater part of the lateral wall anterior to the supra-ampullary ridge. The inner surface of the plate in question is furnished with numerous longitudinal ridges. These ridges are about 10 μ in height, and have a mane-like fringe of yellowish setae measuring ca. 90 μ in length. The posterior border of this chamber carries a dorsal, and a pair of intermediate and ventral lappets projecting freely into the intestine. The dorsal lappet is broadest of all, strongly concavo-convex with convex surface dorsally, rounded on posterior border. The intermediate lappets are slender, pointed at tip, about twice the length of the dorsal lappet, covered with sparsely set fine hairs. The ventral ones are minute, acute at apex, pubescent as in the intermediate ones. The lumen of this chamber becomes gradually narrower posterioly by a lateral constriction, and divided into dorsal and ventral rooms by inner setose elevations of the supra-ampullary ridges. The dorsal room directly opens anteriorly into the cardiac chamber, and posteriorly into the intestine. The ventral room is much smaller than the dorsal one, a triangular diverticulum or ampulla, widened posteriorly, communicating with the dorsal room only by a narrow slit. This room is again divided into right and left divisions by a large longitudinal median elevation raised from its ventral wall. The median elevation is inverted v-shaped in cross-section, produced posteriorly into a tomentous tongue-like process, furnished with numerous longitudinal rides bearing a mane-like fringe of hairs on inner surface as is the case with the ampullary plate.

B. OSSICLES FOUND ON STOMODAEAL APPARATUS

Among the calcified elements developed on the stomodaeal apparatus, the following ossicles are of special interest for the purpose of the present investigation, viz., (1) cardiac plate, (2) cardiac, (3) pterocardiac, (4) urocardiac, (5) zygocardiac, (6) prezygocardiac, and (7) prepyloric ossicles, which will be described below.

a. Cardiac plate

The cardiac plates are a pair of ill-defined ones lying on each side of the cardiac chamber, sometimes partly calcified, posteriorly continuous to the zygo-cardiac ossicles, armed with many upstanding spinules on the inner surface. The spinules are usually acutely pointed, set subequidistantly and arranged in a longitudinal row, variable in number. The number of the spinules ranges from 4 to 43, 20–30 in most cases (45.6%) throughout all the species dealt with (Table 10).

Table 10.

Number of spinules	Frequency	Percentage
0—10	6	8.8
10—20	20	29.4
20—30	31	45.6
30—40	9	13.3
40—50	2	2.9
Total	68	100.0

Remarkably enough, the number of the spinules in question is less than ten in all other species of *Eusicyonia* except *E. curvirostris*. In passing, it should be noticed that each of the teeth of *Aristacomorpha foliacea* is compressed, assuming a low longitudinal ridge.

b. Cardiac ossicle

The cardiac ossicle is a small well-calcified plate-like one, lying on posterior median wall, immediately in front of the urocardiac ossicle, subrectangular in outline.

c. Pterocardiac ossicle

The pterocardiac ossicle is a paired one, usually rather calcified, bar-shaped, laid down postero-lateral to the cardiac ossicle and antero-lateral to the urocardiac ossicle running sidewise. The outer extremity comes into contact with the prezygocardiac ossicle. The general feature shows considerable modification throughout all the species placed at the author's disposal. But the following three sharply defined supra-generic subdivisions regarding the shape of this ossicle, namely, Types, Q_1–Q_3, may be recognized.

Type–Q_1: The ossicle of this type is usually gently narrowed toward outer end, slightly arcuate with convex margin forward, pointed at outer extremity. Antero-median angle considerably produced anteromedially with pointed apex and almost straight anterior and posterior borders, posterior border of which runs parallel with antero-lateral border of urocardiac ossicle. Anterior border rarely swollen and wavy (Fig. 71, *A–D*).

Exemplified by the annexed 12 genera representing 3 subfamilies: *Aristaeus*, *Aristaeomorpha*, *Parahaliporus*, *Penaeus*, *Trachypenaeus*, *Trachypenaeopsis*, *Atypopenaeus*, *Penaeopsis*, *Metapenaeopsis*, *Metapenaeus*, *Parapenaeopsis*, and *Miyadiella*.

Type–Q_2: the ossicle of the present type closely resembles that of the preceding type, especially that of *Penaeus* in general feature, but somewhat wider than that of the type–Q_1. Outer extremity is bifurcate for reception of prezygocardiac ossicle (Fig. 71, *E*).

Only two genera, *Hymenopenaeus* and *Solenocera* are included in this type.

Type–Q_3: the ossicle belonging to this type is narrowed toward pointed outer end, and sigmoid as it is strongly arcuate with convex margin anteriorly in a greater part and suddenly bends antero-laterally near outer extremity. Both antero- and postero-median angles produced antero-medially and postero-medially respectively. Median border almost straight running parallel to antero-lateral border of urocardiac ossicle as in that of the preceding two types. Anterior border has a large pointed

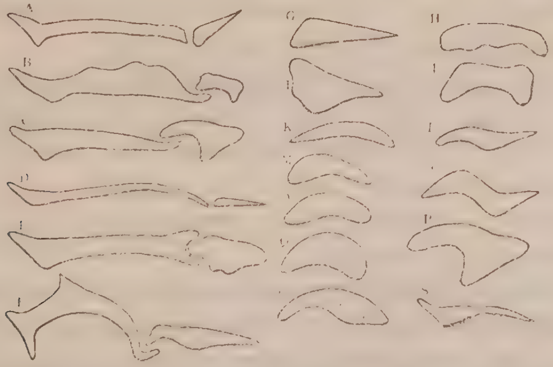

Fig. 71. Ptero-cardiac ossicles referable three types, Type–Q_1 (*A–D*), Type–Q_2 (*E*), and Type–Q_3 (*F*), and prezygocardiac ossicles (*G–S*). A and *G*, *Penaeus japonicus*; *B* and *J*, *Parapenaeopsis sculptilis*; *C* and *P*, *Metapenaeopsis barbatus*; *D*, *Aristaeomorpha foliacea*; *E*, *Solenocera alticarinata*; *F* and *L*, *Penaeopsis rectactus*; *H*, *Hymenopenaeus aequalis*; *I*, *Paraharipolus sibogae*; *K*, *Trachypenaeus curvirostris*; *M*, *Parapenaeopsis hungerfordi*; *N*, *Atypopenaeus compressipes*; *O*, *Parapenaeopsis*; *R*, *Metapenaeus affinis*; *S*, *Aristaeomorpha foliacea*.

process directed antero-medially, somewhat or much nearer to inner end than to outer one.

This type is represented by *Parapenaeus* and *Penaeopsis* only.

d. Urocardiac ossicle

The urocardiac ossicle is a subrectangular median one, well calcified, located a little posterior to cardiac ossicle, posteriorly fused with prepyloric ossicle. Anterior margin rounded or emarginate. Lateral borders straight, provided with a pair of large pointed processes directed sidewise near anterior margin (Figs. 72–77).

e. Zygocardiac ossicle

The zygocardiac ossicle is set on lateral wall of cardiac chamber, anteriorly touches cardiac plate and posteriorly lateral wall of pyloric chamber, usually well calcified, deltoid in outline, much thicker than all other ossicles, markedly convex on outer surface, provided with many teeth on inner surface.

This ossicle is referable to the following six types, viz., Types–R_1–R_6, taking mode of arrangement, number, and shape of the teeth set on the inner surface into consideration.

Type–R_1: the teeth are usually conical in shape and set rather sparsely, arranged in a longitudinal row along almost the same level of the spinules of cardiac plate, and gradually diminish in size posteriorly. The foremost tooth is placed on anterior border of this ossicle, and greatly larger than others. The number of the teeth ranges from 4 to 29, mostly about 10 (Figs. 77, *M–V*, and 78, *A–F*).

All the species ascribable to *Aristaeomorpha*, *Aristaeus*, and *Penaeus* are embraced in this type. The following facts should be noticed herewith. The teeth of *Penaeus vannamei* are transversely strongly compressed and very closely set. The ossicle of *Aristaeomorpha foliacea* is somewhat deviated from typical form of this type, but tentatively placed in this catagory.

Type–R_2: the type closely resembles type–R_1. But the discrepancy is that the teeth of this type are set rather irregularly (Fig. 78, *G–K*).

Parapenaeus and *Penaeopsis* belong to the present type.

Type–R_3: two or three large pointed teeth are present along anterior border. The upper tooth is usually followed by many accessory teeth which are pointed at apex, alined longitudinally, and become smaller backward. The intermediate one is sometimes absent. The lower one stands at anterior end of ventral border of the ossicle. Besides these, many slender spinous teeth exist on ventral border and inner surface posterior to the large teeth given above (Figs. 78, *L–P*, and 79).

This type involves *Parapenaeopsis*, *Trachypenaeus*, *Atypopenaeus*, *Miyadiella*, and *Eusicyonia*. Remarkably enough, the intermediate tooth inserted on the anterior border of this ossicle is absent in *Eusicyonia* without exception.

Type–R_4: two or three rather large teeth present on anterior border of the ossicle as is the case with Type–R_3. A longitudinal series of slender acute teeth exists, the foremost tooth of the series is situated immediately dorsal or a little postero-dorsal to the uppermost teeth set on the anterior border. The teeth of the series get gradually smaller posteriorly (Fig. 80, *A–I*).

This type is peculiar to *Solenocera* and *Hymenopenaeus*.

Type–R_5: two large conical teeth are always present on anterior border. Upper one of them is usually followed by 1–4 small teeth arranged longitudinally (Figs. 80, *J–N*) and 81, *A–D*).

Metapenaeopsis and *Parahaliporus* belong to the present type. The accessory teeth of the upper large conical tooth are absent in *M. coniger* and *M. latus*.

Type–R_6: the ossicle furnished with two longitudinal series composed of many rather closely set pointed teeth. The teeth of each series diminish in size posteriorly, those of upper series are sometimes rather vestigial, and those of lower one are set along lower border of the ossicle and sometimes get successively longer toward middle of the series (Fig. 81, *E–M*).

Represented by *Metapenaeus* and *Trachypenaeopsis*.

f. Prezygocardiac ossicle

Prezygocardiac ossicle minute, ill-calcified, found to exist between cardiac plate and ptero-cardiac ossicle. As exhibited in Fig. 71, *G–S*, it varies considerably in shape: triangular, crescentic, sigmoid or their modified forms.

g. Prepyloric ossicle

The prepyloric ossicle is a wedge-shaped median plate, well calcified, gradually narrowed posteriorly into a tooth which is pointed or truncate at apex, considerably recurved downward in distal half, concavo-convex with convex surface upward, articulated with anterior border of dorsal wall of the pyloric chamber, projected postero-ventrally into the narrow passage between cardiac and pyloric chamber, and movable back and forth. The anterior or upper border is usually straight, but sometimes concave. Each postero-lateral border is armed in most cases with many pointed teeth which are yellowish brown in alcoholic material, and rarely has no teeth.

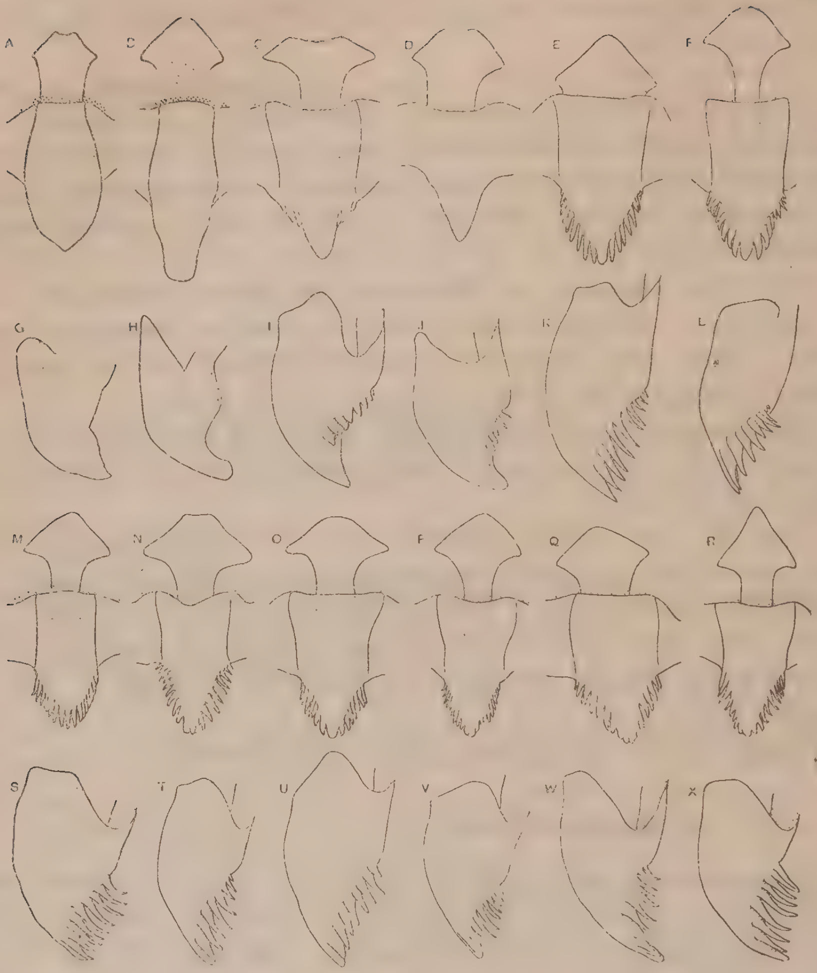

Fig. 72. Upper aspect of urocardiac and prepyloric ossicles (*A-F* and *M-R*), and lateral aspect of prepyloric ossicle (*G-L* and *S-X*). *A* and *G*, *Aristaeomorpha foliacea*; *B* and *H*, *Aristaeus virilis*; *C* and *I*, *Hymenopenaeus lucassi*; *D* and *J*, *Hymenopenaeus aequalis*; *E* and *K*, *Parahaliporus sibogae*; *F* and *L*, *Solenocera prominentis*; *M*, and *S*, *Solenocera subnuda*; *N* and *T*, *Solenocera pectinulata*; *O* and *U*, *Solenocera depressa*; *P*, and *V*, *Solenocera alticarinata*; *Q* and *W*, *Solenocera brevipes*; *R* and *X*, *Solenocera faxoni*. *A* and *G*, ×6; *B* and *H*, ×8.4; *C*, ×14; *D*, ×22; *E*, *F*, *L*, and *P*, ×16; *I* and *R*, ×18; *J*, *W*, and *X*, ×28; *K*, *Q*, *S*, and *V*, ×20; *M*, ×12; *N*, ×32; *O*, ×16.4; *T*, ×40; *U*, ×24.

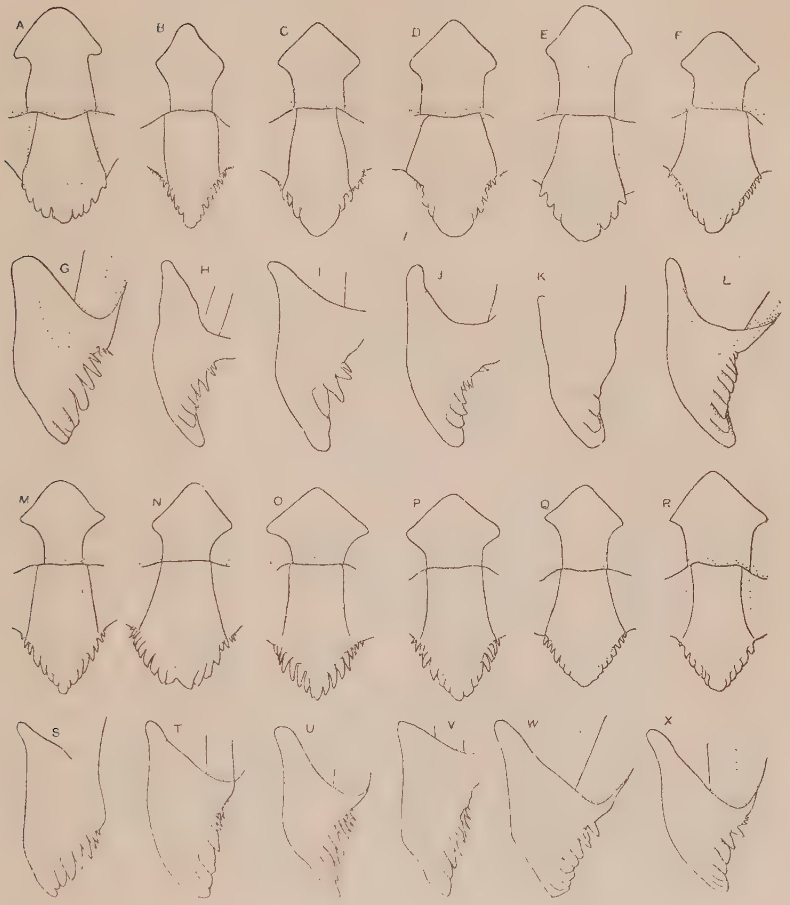

Fig. 73. Upper aspect of urocardiac and prepyloric ossicles (*A–F* and *M–R*), and lateral aspect of prepyloric ossicle (*G–L* and *S–X*). *A* and *G*, *Penaeus japonicus*; *B* and *H*, *Penaeus latisulcatus*; *C* and *I*, *Penaeus longistylus*; *D* and *J*, *Penaeus teraoi*; *E* and *K*, *Penaeus monodon*; *F* and *L*, *Penaeus bubulus*; *M* and *S*, *Penaeus orientalis*; *N* and *T*, *Penaeus indicus*; *O* and *U*, *Penaeus merguiensis*; *P* and *V*, *Penaeus penicillatus*; *Q* and *W*, *Penaeus esculentus*; *R* and *X*, *Penaeus stylirostris*. *A*, *M* and *R*, ×6; *B*, *C*, *G*, *L*, *N*, *S*, and *X*, ×8.4; *D*, *P*, and *Q*, ×8.8; *E*, ×9.6; *F*, ×5.2; *H–K*, *T*, *V*, and *W*, ×12; *U*, ×16.

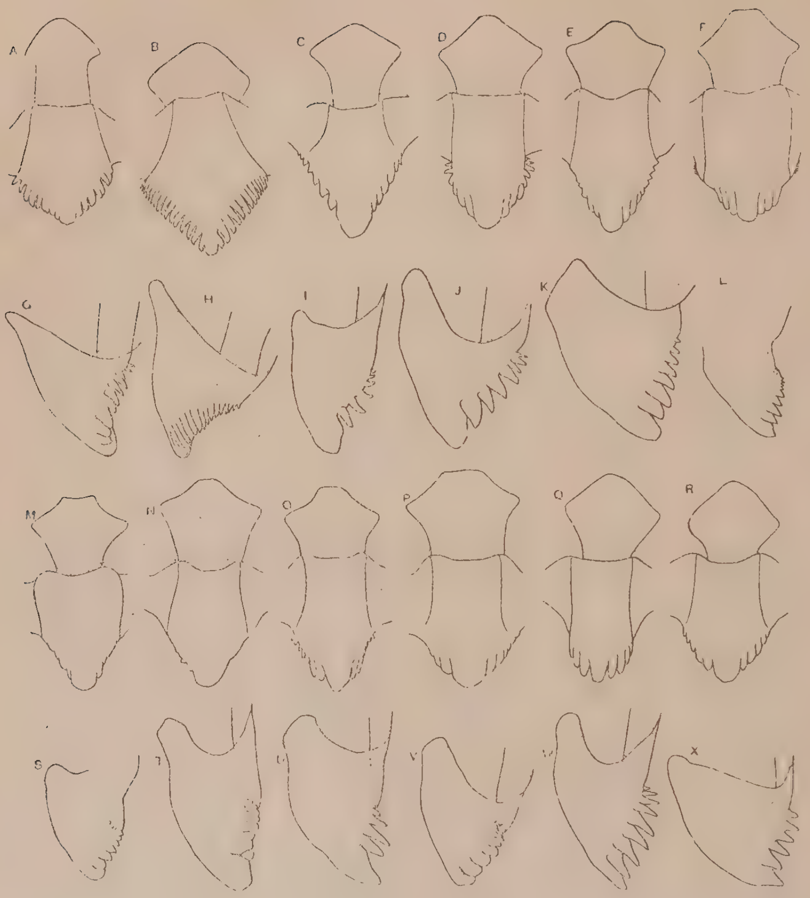

Fig. 74. Upper aspect of urocardiac and prepyloric ossicles (*A*–*F* and *M*–*R*) and lateral aspect of prepyloric ossicle (*G*–*L* and *S*–*X*). *A* and *G*, *Penaeus brevirostris*; *B* and *H*, *Penaeus vannamei*; *C* and *I*, *Miyadiella pedunculata*; *D* and *J*, *Metapenaeus monoceros*; *E* and *K*, *Metapenaeus joyneri*; *F* and *L*, *Metapenaeus affinis*; *M* and *S*, *Metapenaeus spinulatus*; *N* and *T*, *Metapenaeus tenuipes*; *O* and *U*, *Metapenaeus lysianassa*; *P* and *V*, *Metapenaeus brevicornis*; *Q* and *W*, *Metapenaeus intermedius*; *R* and *X*, *Trachypenaeopsis richtersii*. *A*, *J*. *P*, and *W*, ×12; *B*, ×8.4; *C* and *I*, ×64; *D* and *Q*, ×8.8; *E*, ×10; *F*, *L*, *M*, *S* and *V*, ×16; *G* and *N*, ×20; *H*, ×9.2; *K*, ×13.6; *O*, ×24; *R* and *T*, ×28; *U*, ×31.6; *X*, ×32.

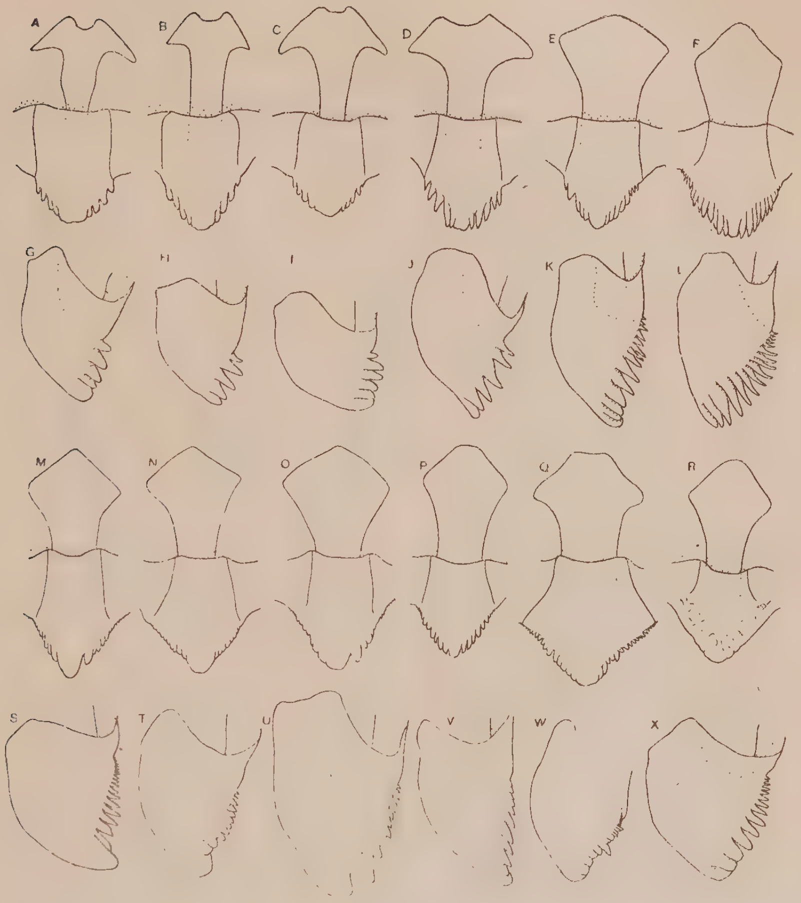

Fig. 75. Upper aspect of urocardiac and prepyloric ossicles (*A–F* and *M–R*), and lateral aspect of prepyloric ossicle (*G–L* and *S–X*). *A* and *G*, *Parapenaeus fissurus*; *B* and *H*, *Parapenaeus sextuberculatus*; *C* and *I*, *Parapenaeus lanceolatus*; *D* and *J*, *Parapenaeus investigatoris*; *E* and *K*, *Parapenaeopsis tenellus*; *F* and *L*, *Parapenaeopsis cornutus*; *M* and *S*, *Parapenaeopsis hardwickii*; *N* and *T*, *Parapenaeopsis cultrirostris*; *O* and *U*, *Parapenaeopsis sculptilis*; *P* and *V*, *Parapenaeopsis hungerfordi*; *Q* and *W*, *Trachypenaeus curvirostris*; *R* and *X*, *Trachypenaeus asper*, *A* and *M*, ×10; *B*, ×14; *C*, *H*, *N*, and *W*, ×20; *D*, ×20.8; *E*, ×22; *F* and *R*, ×16.8; *G*, *Q*, and *S*, ×16; *I*, *J*, *L*, *T*, *V*, and *X*, ×28; *K*, ×32; *O*, ×7.2; *R*, ×24; *U*, ×12.

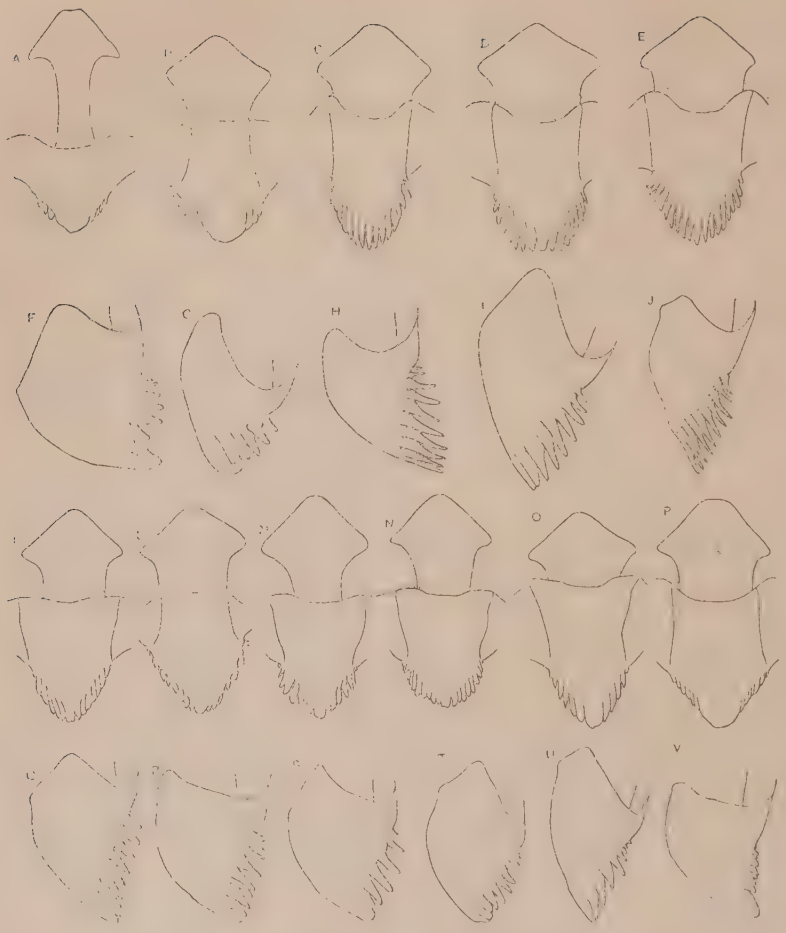

Fig. 76. Upper aspect of urocardiac and prepyloric ossicles (*A–E* and *K–P*), and lateral aspect of preyloric ossicle (*F–J* and *Q–V*). *A* and *F*, *Penaeopsis rectactus*; *B* and *G*, *Atypopenaeus compressipes*; *G* and *H*, *Metapenaeopsis barbatus*; *D* and *I*, *Metapenaeopsis acclivis*; *E* and *J*, *Metapenaeopsis durus*; *K* and *Q*, *Metapenaeopsis dalei*; *L* and *R*, *Metapenaeopsis incomptus*; *M* and *S*, *Metapenaeopsis coniger*; *N* and *T*, *Metapenaeopsis latus*; *O* and *U*, *Metapenaeopsis lamellatus*; *P* and *V*, *Eusicyonia cristata*. *A*, ×9.2; *B*, *I*, *S*, and *T*, ×28; *C*, *L*, *U*, and *V*, ×16; *D*, *F*, *H*, *M*, and *R*, ×20; *E*, ×17.2; *G*, ×40; *J*, ×20.8; *K*, ×18; *N*, ×21.6; *O*, ×12; *P*, ×12.8; *Q*, ×28.

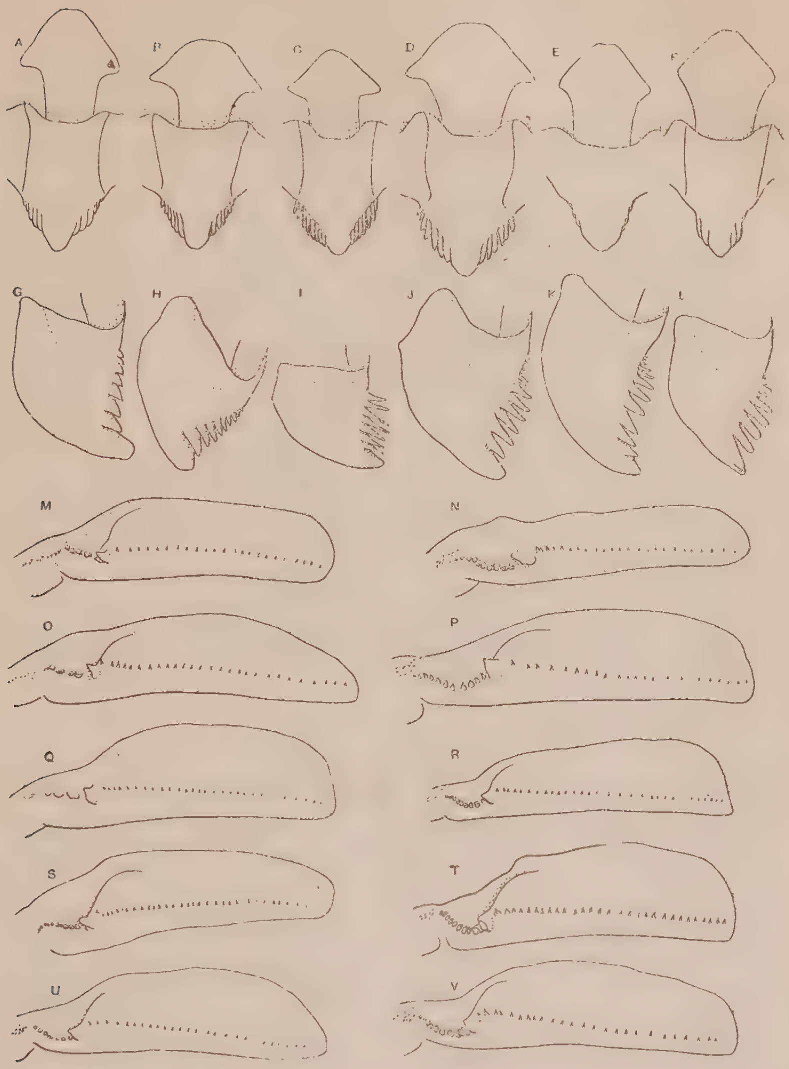

Fig. 77. Upper aspect of urocardiac and preyloric ossicles (*A–F*), lateral aspect of prepyloric ossicle (*G-L*), and inner aspect of cardiac plate and zygocardiac ossicle (*M–V*). *A* and *G*, *Eusicyonia truncata*; *B* and *H*, *Eusicyonia nebulosa*; *C* and *I*, *Eusicyonia inflexa*; *D* and *J*, *Eusicyonia curvirostris*; *E* and *K*, *Eusicyonia lancifer japonica*; *F* and *L*, *Eusicyonia vitulans*; *M*, *Penaeus japonicus*; *N*, *Penaeus monodon*; *O*, *Penaeus latisulcatus*; *P*, *Penaeus bubulus*; *Q*. *Penaeus longistylus*; *R*, *Penaeus orientalis*; *S*, *Penaeus teraoi*; *T*, *Penaeus indicus*; *U*, *Penaeus penicillatus*; *V*, *Penaeus merguiensis*. *A*, *J*, and *L*, ×28; *B*, ×40; *C*, ×16.8; *D*, and *F*, ×24; *E*, ×10.8; *G*, ×32; *H*, ×44; *J* and *K*, ×20; *M*, *N*, and *T*, ×4.8; *O*, and *U*, ×6; *P* and *R*, ×2; *Q*, ×5.2; *S*, ×12; *V*, ×6.4:

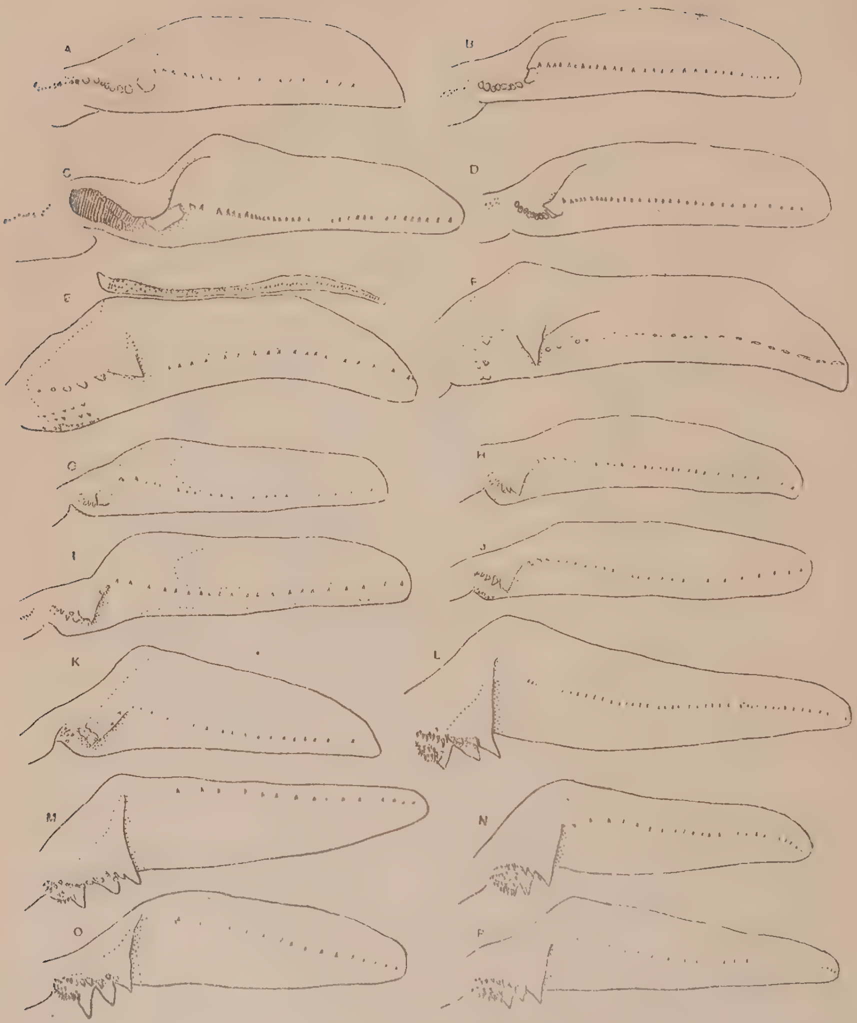

Fig. 78. Inner aspect of cardiac plate and zygocardiac ossicle. *A*, *Penaeus esculentus*, ×6; *B*, *Penaeus stylirostris*, ×6; C. *Penaeus vannamei*, ×6; *D*, *Penaeus brevirostris*, ×6.4; *E*, *Aristaeus virilis*, ×6; *F*, *Aristaeomorpha foliacea*, ×4.8; *G*, *Parapenaeus fissurus*, ×6; *H*, *Parapenaeus sextuberculatus*, ×8.4; *I*, *Parapenaeus lanceolatus*, ×12; *J*, *Parapenaeus investigatoris*, ×12; *K*, *Penaeopsi rectacius*, ×6; *L*, *Parapenaeopsis cornutus*, ×6; *M*, *Parapenaeopsis cultrirostris*, ×14; *N*, *Parapenaeopsis tenellus*, ×16; *O*, *Parapenaeopsis hardwickii*, ×8.4; *P*, *Parapenaeopsis hungerfordi*, ×12.

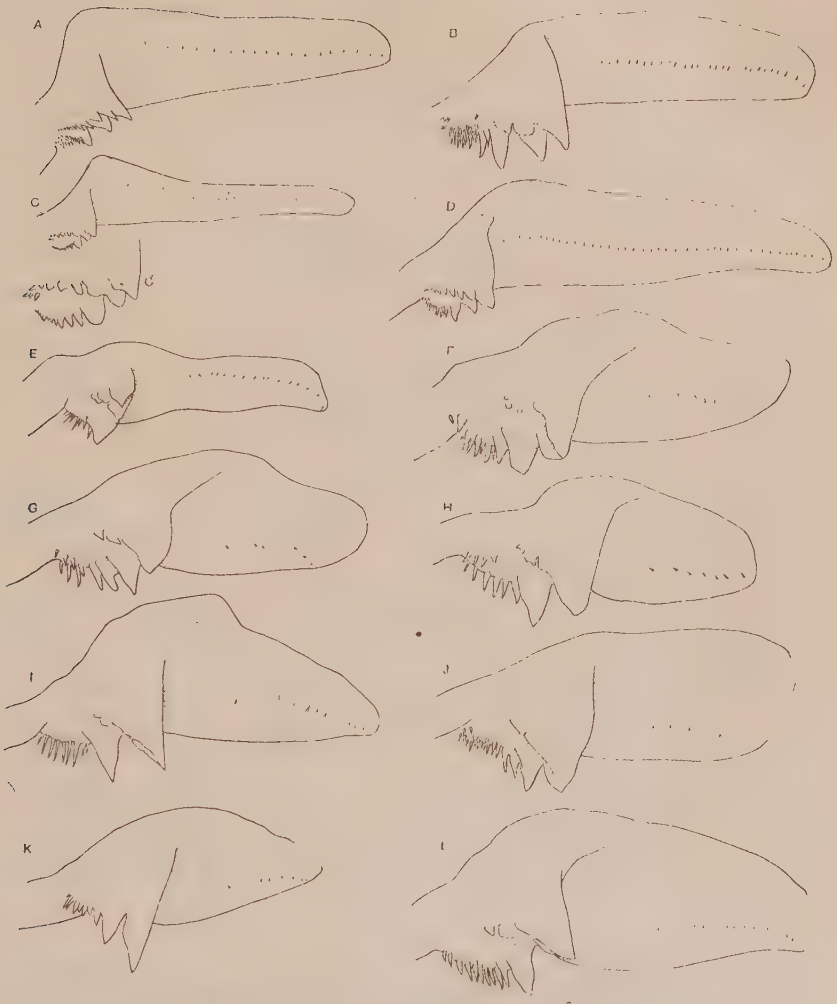

Fig. 79. Inner aspect of cardiac plate and zygocardiac ossicle. *A*, *Parapenaeopsis sculptilis*, ×4.8; *B*, *Atypopenaeus compressipes*, ×28; *C*, *Trachypenaeus curvirostris*, ×6; *D*, *Trachypenaeus asper*, ×12; *E*, *Miyadiella pedunculata*‘ ×44; *F*, *Eusicyonia cristata*, ×16; *G*, *Eusicyonia inflexa*, ×16; *H*, *Eusicyonia lancifer japonica*, ×16; *I*, *Eusicyonia vitulans*, ×24; *J*, *Eusicyonia truncata*, ×28; *K*, *Eusicyonia nebulosa*, ×32; *L*, *Eusicyonia curvirostris*, ×24.

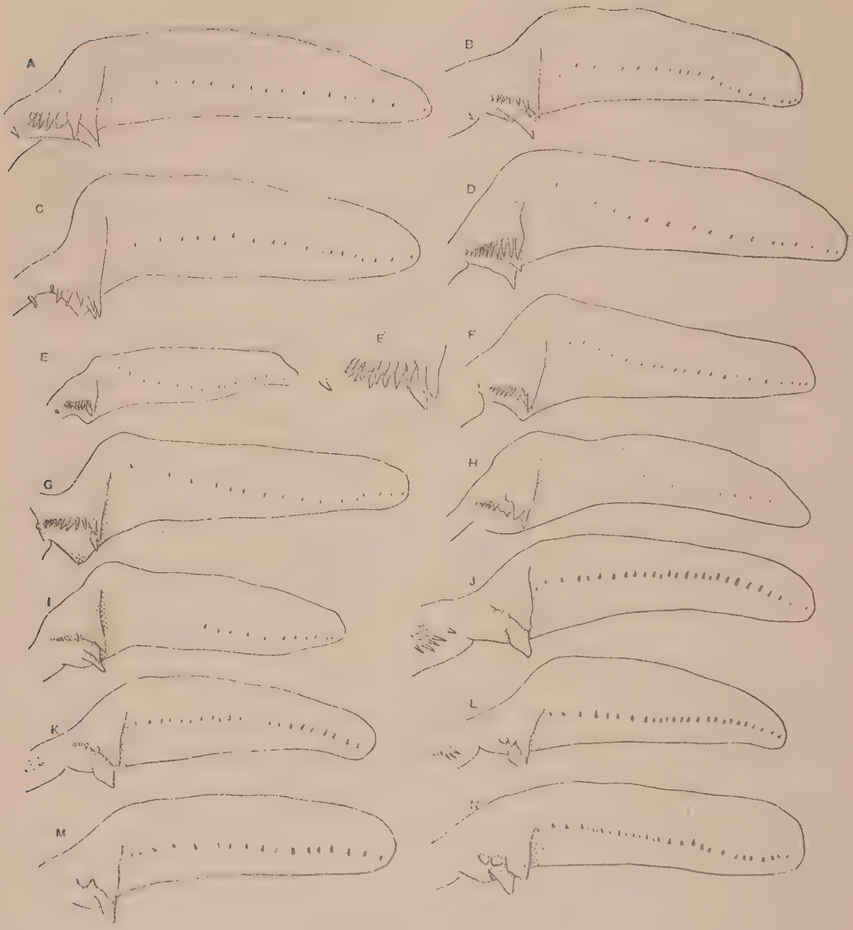

Fig. 80. Inner aspect of cardiac plate and zygocardiac ossicle. *A, Solenocera brevipes,* ×14; *B, Solenocera pectinulata,* ×28; *C, Solenocera faxoni,* ×12; *D, Solenocera subnuda,* ×8.8; *E, Solenocera prominentis,* ×4.8 (*c′*, ×12); *F, Solenocera alticarinata,* ×8.8; *G, Solenocera depressa,* ×12; *H, Hymenopenaeus lucasii,* ×8.4; *I, Hymenopenaeus aequalis,* ×16; *J, Metapenaeopsis barbatus,* ×12; *K, Metapenaeopsis acclivis,* ×14; *L, Metapenaeopsis durus,* ×10; *M, Metapenaeopsis* dalei, ×12; *N, Metapenaeopsis incomptus,* ×12.

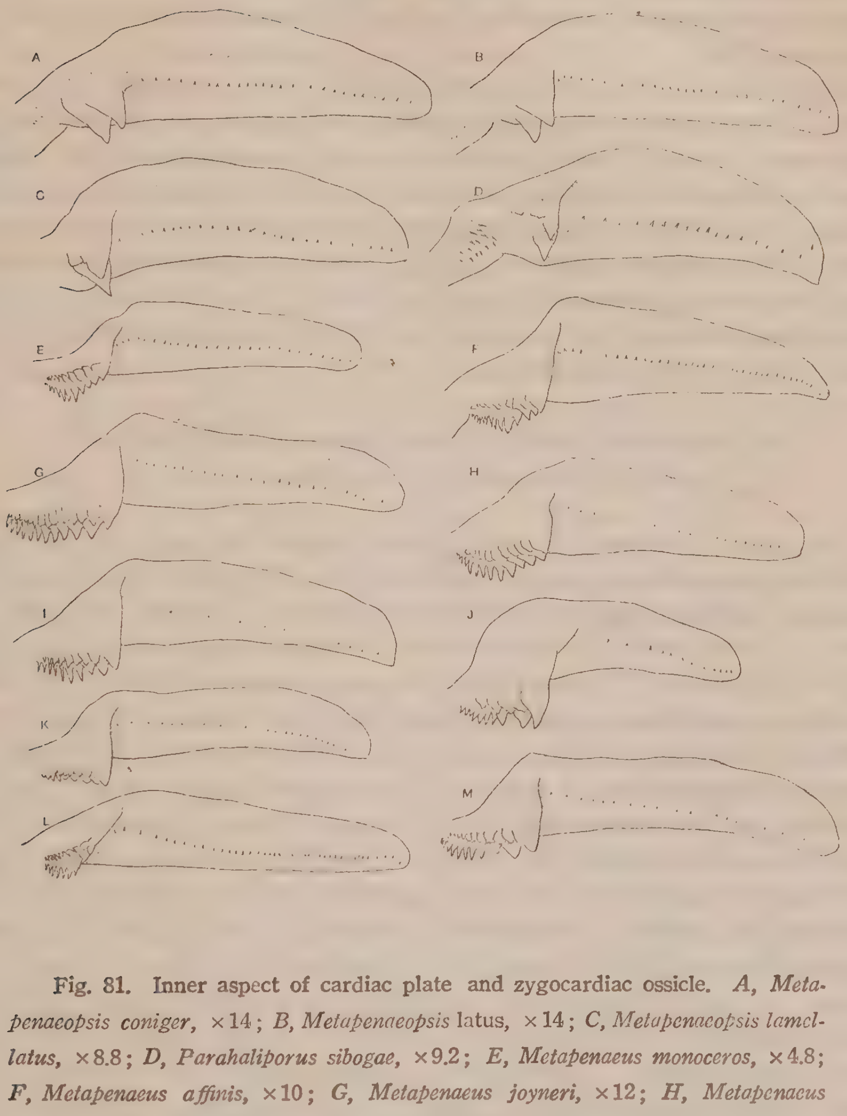

Fig. 81. Inner aspect of cardiac plate and zygocardiac ossicle. *A, Metapenaeopsis coniger,* ×14; *B, Metapenaeopsis* latus, ×14; *C, Metapenaeopsis lamellatus,* ×8.8; *D, Parahaliporus sibogae,* ×9.2; *E, Metapenaeus monoceros,* ×4.8; *F, Metapenaeus affinis,* ×10; *G, Metapenaeus joyneri,* ×12; *H, Metapenaeus tenuipes,* ×12; *I, Metapenaeus lysianassa.* ×16; *J, Trachypenaeopsis richtersii,* ×28; *K, Metapenaeus spinulatus,* ×8.4; *L, Metapenaeus intermedius; M, Metapenaeus brevicornis,* ×8.4.

Owing to presence or absence of the teeth inserted along the postero-lateral borders, two types, S_1 and S_2, may be recognized.

The Type–S_1 (Fig. 72, *A*, *B*, *G* and *H*) is represented by only such forms as referable to Aristaeinae, namely, *Aristaeemorpha foliacea* and *Aristaeus virilis*.

The type–S_2 (Figs. 72, *C–F*∼*I–X*, 77, *A–L*) embraces all other species dealt with except the two which belong to the type–S_1. The tooth located at apex of the ossicle in question is almost always remarkably or somewhat larger than the teeth attached to the postero-lateral borders. The ossicle of *Hymenopenaeus* demonstrates some intermediate condition between the types, S_1 and S_2, since the teeth of each postero-lateral border are somewhat vestigial (Fig. 72, *C*, *D*, *I* and *J*). It is interesting that the type–S_1 is, so far as the present inspection goes, characteristic to deep-sea forms.

C. TAXONOMIC AND PHYLOGENETICAL CONSIDERATIONS ON STOMODAEAL APPARATUS

The general feature of stomach and that of the straining apparatus found in the pyloric chamber are invariable throughout all the species on hand. The cardiac plate is almost unique in shape, although the plate of *Eusicyonia* is comparatively shorter than that of all other species dealt with. The number of spinules set on the inner surface of the plate in question is usually species-specific, though it shows some extent of variation within a species. This character, however, not valuable for distiaction of genera. The cardiac ossicle is also variable in shape, but the variation seems to be considerably influenced by the degree of calcification of the ossicle. Thus this character can not be of importance as a criterion for the taxonomy of the present family. The ptero-cardiac ossicle demonstrates remarkable modification in general configuration, but three types, Q_1–Q_3 have been recognized as set forth already. The type–Q_1 is most generalized, and probably most primitive among the three. The type–Q_2 is peculiar to the genera, *Solenocera*, and *Hymenopenaeus*. The type–Q_3 is characteristic to the genus, *Parapenaeus*, and it may be newly added to the generic character of the genus as a significant trait. The urocardiac ossicle affords nothing for the classification of the Penaeids, because the ossicle undergoes little variation in feature throughout all the species examined. The prezygocardiac ossicle (Fig. 71) is minute, triangular, with apex anteriorly in *Penaeus* and *Parahaliporus*, invertedly triangular and proximally curved backward with bluntly pointed inner end in *Metapenaeopsis* and sigmoid in *Atypopenaeus*, *Parapenaeus* and *Penaeopsis*. It seems to be peculiar to the species of Aristaeinae that the ossicle is furnished with many pointed spinules on inner surface. Especially the ossicle of *Aristaeomorpha foliacea* is astonishingly elongated reaching almost anterior border of the cardiac plate. In the rest, the ossicle is crescentic and modified in feature. However, this character is less valuable as a systematic criterion inasmuch as it is not only too minute, but also considerably variable even within a species. The zygocardiac ossicle is invariable in shape, whilst it is referable to six sharply defined supergeneric (Types, R_1–R_6) categories regarding its spinescence. The type-R_1 is represented by *Penaeus*, *Aristaeus* and *Aristaeomorpha*, Type-R_2 by *Parapenaeus* and *Penaeopsis*, Type-R_3 by *Penaeopsis*, *Trachypenaeus*, *Miyadiella*, *Atypopenaeus*, and *Eusicyonia*, Type-R_4 by *Solenocera* and *Hymenopenaeus*, Type-R_5 by *Metapenaeopsis* and *Parahaliporus*, and Type-R_6 by *Metapenaeus* and *Trachypenaeopsis*. Thus the demarkation between *Metapenaeopsis* and *Metapenaeus* becomes clear and precise, although exact delimitation between those two genera has long been a matter of considerable difficulty as based on the external characters only. With regard to prepyloric ossicle, two distinct types, S_1 and S_2, are recognized. The type-S_1 is confined to species *Aristaeus virilis* and *Aristaeomorpha foliacea*. The type-S_2 is common to all other genera examined. The shape of the type-S_2 furnishes no specific character, but the number of the teeth arranged along each postero-lateral border is species-specific in many cases.

Among the internal characters treated in this research, the pterocardiac and zygocardiac ossicles seem to furnish some conjectures for the phylogeny of the present family. As regards the general feature of the pterocardiac ossicle, three types, Q_1–Q_3, are recognized as given above. The present author is inclined to take the type-Q_1, simply bar-shaped, ancestral to two divergent stems represented by the type-Q_2, bifid at outer end, and type-Q_3, sigmoid with a pointed process near middle of the anterior border, because the type-Q_1 is most generalized and simplest in shape. The zygocardiac ossicle has been ascribed to six types, R_1–R_6, regarding mostly mode of arrangement of the teeth laid down on its inner surface. It is not without reason to consider, therefore, that there are three offshoots sprang from a common ancestral form. The first and third are represented by the type-R_1, and type-R_6 respectively. The second or intermediate offshoot is reprented by the remaining four types, Type-R_2–R_5, to which the offshoot branches. Of these four types, the type-R_2 may be taken as the most primitive and has close resembrance to type-R_1. The type-R_3 stands nearer to the type-R_4 than to the type-R_5 which is intermediate between the types, R_2 and R_3.

Moreover, for morphological comparison and phylogenetical discussion, the writer has undertaken an examination dissecting stomach of the following crustaceans, viz., *Sergestes lucens* HANSEN, *Acetes japonicus* KISHINOUYE, *Palaemon carcinus* FABRICIUS, *Stenopus hispidus* OLIVIER, *Nephropus japonicus* TAPPARONE-CANEFERI, *Nephropsis stewarti* WOOD-MASON, *Cambarus clarkii* (GIRARD) and *Cambaroides japonicus* (DE HAAN). Of these the first two belong to Penaeidea (Sergestidae), the third to Caridea, the fourth to Stenopidea, and the last four to Astacidea.

The stomodaeal apparatus of a specimen of *Sergestes lucens*, 56 mm long, secured from Suruga Bay, closely resembles that of the Penaeids dealt with in general aspect. Salient differences are found, however, mostly in scleritic elements. In *S. lucens*, the pterocardiac ossicle is not defined; the cardiac plate is destitute of spinules on inner surface; the prepyloric ossicle is bifurcated at apex like that of crayfishes, the armatures set along each postero-lateral border are minute; (Fig. 82, *A* and *B*) and the cardio-pyloric valve is less developed than that of the Penaeids.

In a specimen of *Acetes japonicus*, 38 mm long, obtained from west coast of Korea, the organ in question is closely allied to that of *Sergestes lucens* in general facies, though it is nearer to that of the Penaeids than to that of *Sergestes lucens* in the following respects, viz., general feature of the prepyloric ossicle and condition of armatures lying on inner surface of zygocardiac ossicle (Fig. 82, *D–G*).

The stomach of a large male of *Palaemon carcinus*, from French Indo-China, measuring 165 mm long, is in much simpler condition having the roof and lateral walls of the cardiac chamber quite membranous and no ossified elements. But the cardio-pyloric valve and the straining apparatus found in the pyloric ampulla are more pronounced than those of the Penaeids. The pyloric fold is not defined as in Astacidae.

The stomach of an ovigerous female of *Stenopus hispidus*, 60 mm long, secured from Prov. Bōsyū, the cardiac ossicle is lunate in outline with convex border anteriorly comparatively larger than that of the Penaeids, and comes into contact with the urocardiac ossicle along its posterior edge. The ptero-cardiac ossicle is remarkably developed, and attached to the lateral rim of the cardiac ossicle and to the antero-lateral rim of the uro-cardiac one. Presence of the prezygo-cardiac ossicle is not ascertained. The teeth of the zygocardiac ossicle are somewhat rudimentary and differ in arrangement from those of the Penaeids. The prepyloric ossicle more or less reminds one of that of crayfishes in apical aspect, but armed with many small conical teeth along postero-lateral borders as in that of the Penaeids. The cardiac chamber has no cardiac plates and spinules on the lateral walls like that of crayfishes. The cardio-pyloric valve is similar to that of *Palaemon carcinus* and the *Penaeids* in general aspect. The pyloric fold is not defined. The lateral walls of the pyloric chamber are furnished with a transverse series made up of seven closely set conical teeth, somewhat posterior to the zygocardiac ossicle. Each of the pyloric ampulla bulges out dorsally as a wing-like sac, concavo-convex, with rather strongly convex outer surface, circular in lateral view.

In specimens, 140 mm and 125 mm long, secured off Mie Prefecture at a depth of ca. 350 m, of *Nephrops japonicus* and *Nephropsis stewarti* respectively, the scleritic elements of stomodaeal apparatus are much more developed and complex than those of the Penaeids dealt with and *Stenopus hispidus*. The cardiac ossicle is very large occupying almost entire anterior roof of the cardiac chamber, strongly calcified posteriorly, and fused with the urocardiac ossicle. The pterocardiac ossicle is small and curved, but well-calcified, articulated with cardiac ossicle. The prezygocardiac ossicle is not recognized. The prepyloric is pointed at posterior end, and has no teeth on posterolateral borders. The cardiopyloric valve is markedly developed like that of Astacidae. The pyloric ampulla resembles that of *Stenopus hispidus*, *Cambarus clarkii* and *Cambaroides japonicus*. Besides, well defined subdentary and pectineal ossicles are found to exist.

The stomach of *Cambarus clarkii*, 55 mm long, and *Cambaroides*

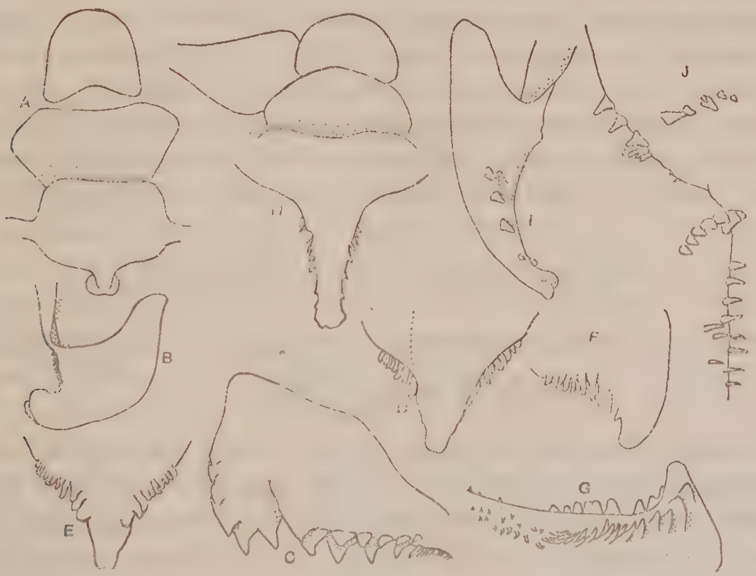

Fig. 82. Stomodaeal ossicles of *Sergestes lucens* HANSEN (*A–C*), *Acetes japonicus* KISHINOUYE (*D–H*), and *Stenopus hispidus* OLIVIER (*I* and *J*). *A*, dorsal view of cardiac, anterior part of urocardiac and prepyloric ossicles; *B*, *F*, and *I*, lateral view of prepyloric ossicle; *C*, *G*, and *J*, zygocardiac ossicles; *D*, dorsal aspect of prepyloric ossicle; *E*, ventral aspect of prepyloric ossicle; *H*, upper aspect of cardiac, inner half of pterocardiac, anterior part of urocardiac, and prepyloric ossicles. *A* and *C*, ×25; *B*, *I*, and *J*, ×35; *D–G*, ×60; *H*, ×20.

japonicus, 48 mm long, agrees well with HUXLEY'S (1888) description, and figures in all important points. Again, it is closely related to that of *Nephrops japonicus* and *Nephropsis stewarti* in general respects, although the calcified elements are considerably stouter than those of the two Nephropsoid forms, and the prepyloric ossicle is bifid at apex instead of being simply pointed.

In short, the stomodaeal apparatus of the Penaeids dealt with is much more intricated than that of Caridea as pointed out by CALMAN (op. cit., p. 282). But it is much simpler than that of crayfishes, Nephropsoid prawns and orabs (PEARSON, 1908, and UENO, 1925). Moreover, degree of calcification of the scleritic elements found in the apparatus of the Penaeids is less than that of the animals of Astacidae and Nephropsidae. Whilst the stomach of *Sergestes lucens*, *Acetes japonicus* and *Stenopus hispidus* is intermediate in general condition of the scleritic elements between that of the Penaeids and the crayfishes. It is of much interest from view point of phylogeny, that the three species belonging to Sergestidae and Stenopidae are more related to such crayfishes and Nephropsoid forms than to the Penaeids in the following important respects, viz., cardiac plate has no spinules on inner surface, and prepyloric ossicle is bifurcate at apex.

Finally the fact given in the following lines is worth mentioning. The stomodaeal apparatus of Penaeids dealt with is much more complex than that of *Cerataspis monostrosus* (CALMAN, *op. cit.*), which is a primitive Penaeid, in general feature owing to appearance of cardiac, pterocardiac, prezygocardiac, zygocardiac with strikingly developed teeth, prepyloric ossicles, median, lateral, pyloric ridges, and so forth.

3. PHYLOGENETICAL CONSIDERATION

A. INTERRELATIONSHIP AMONG SUBFAMILIES AND GENERA OF THE FAMILY PENAEIDAE

In dealing with the phylogeny of the sixteen genera, to which all the specimens on my hands are referable, nineteen important characters enumerated below are particularly taken into consideration, viz., (a) carapace, (b) telson, (c) ophthalmopoda, (d) antennule, (e) mandible, (f) maxillula, (g) maxilla, (h) first maxilliped; (i) third maxilliped, (j) exopodites of thoracic appendages, (k) spines set on the thoracic appendages posterior to third maxilliped, (l) branchial arrangement, (m) petasma, (n) thelycum, (o) appendix masculina, (p) endopodite of pleonic appendages, (q) pterocardiac ossicle, (r) zygocardiac ossicle, and (s) prepyloric one.

To tell relative importance of these characters, however, is no easy task. Thus, one line for each coincidence is drawn, as shown in Fig. 83, between any two genera, and the number of the lines is assumed to represent the degree of affinity between each pair and the counting of the number of the lines is given in Table 12. Apparently intricate as they are, the lines dissolve into rather clearly defined groupings which represent four already recognized natural affinities, viz., Eusicyoninae, Penaeinae, Aristainae, and Solenocerinae respectively. Therefore, they are termed herein Eusicyoninae-, Penaeinae-, Aristaeinae-, and Solenocerinae-stems. The first two are again genealogically well contrasted to the second two, on basis of the feature of appendix masculina and thelycum. So far as these characters are concerned, Solenocerinae is nearer to Aristaeinae than to Penaeinae as suggested already by BURKENROAD (1936, p. 146), and Eusicyoninae is more closely related to Penaeinae than to Aristaeinae and Solenocerinae.

To begin with Eusicyoninae-stem: this monotypic subdivision is the most specialized one among all the fours in having many features unshared by others, viz., (1) carapace is of Type-A_4, (2) abdomen sculptured on lateral walls, (3) antennule is of Type-D_4, (4) first maxilliped is of Type-H_1, (5) arrangement of exopodites attached to thoracic appendages is of Type-J_4, (6) branchial arrangement is of Type-L_5, (7) petasma is of Type-M_8 (8) thelycum is of Type-N_6, (9) appendix masculina is of Type-O_3, and (10) arrangement of pleonic endopodites belong to Type-P_2. Of these characteristics, the fourth are undoubtedly unparalleled degenerate specialization. The present offshoot, as it appears to the author, is the earliest of all, arising from the common stock from which all of the Penaeid-branches have sprung off.

Penaeinae-stem: This is the largest of all the four, and represented by ten genera: *Miyadiella*, *Penaeus Penaeopsis*, *Metapenaeus*, *Trachypenaeopsis*, *Atypopenaeus*, *Parapenaeopsis*, *Trachypenaeus*, *Parapenaeus*, and *Metapenaeopsis*. Characteristics common to all the genera given above are as follows:—(1) presence of prosartema, (2) mandibular palp is of Type-E_3, (3) first maxilliped is of Type-H_{2a}, (4) presence of exopodite on appendages of abdominal segments from first to sixth, (5) prepyloric ossicle belongs to Type-S_2. Unpossesed by any of other three stems, but found in one or several genera of the Penaeinae-stem are the following traits: appendix masculina is of Type-O_1, O_2, and O_4-O_8, and thelycum belongs to Type-N_2, and N_4-N_8.

The genus, *Miyadiella*, is apparaently the most primitive throughout all the genera dealt with, because of the annexed features: (1) carapace is little specialized, (2) petasmal endopodites are merely leaf-shaped with two strips on distal border, not conjoined with each other along median edge as is the case with the young form of other genera, and (3) appendix masculina resembles earlier stage found in other genera. The

Table 11. Types of characters of the genera. I, carapace; II, telson, III, eye; IV, antennule; V, mandible; VI, maxillula; VII, maxilliped; VIII, first maxilliped; IX, third maxilliped; X, arrangement of thoracic exopodites; XI, arrangement of spines lying on thoracic appendages; XII, branchial arrangement; XIII, petasma; XIV, thelycum; XV, appendix masculina; XVI, pleonic endopodites; XVII, ptero-cardiac ossicle; XVIII, zygocardiac ossicle; XIX, prepyloric ossicle; a, *Aristaeomorpha*; b, *Aristaeus*; c, *Solenocera*; d, *Hymenopenaeus*; e, *Parahaliporus*; f, *Miyadiella*; g, *Penaeus*; h, *Penaeopsis*; i, *Metapenaeus*, j, *Trachypenaeopsis*, k, *Atypopenaeus*; l, *Parapenaeopsis*; m, *Trachypenaeus*; n, *Parapenaeus*; o, *Metapenaeopsis*; p, *Eusicyonia*.

Items	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX
a	A_{2d}	B_1	C_1	D_5	E_1	F_{1a}	G_2	H_{2b}	I_1	J_3	K_2	L_1	M_2	N_1	O_9	P_1	Q_1	R_1	S_1
b	A_{1d}	B_1	C_1	D_5	E_1	F_{1a}	G_1	H_{2b}	I_2	J_3	K_{12}	L_1	M_2	N_1	O_9	P_1	Q_1	R_1	S_1
c	A_{5k}	B_3	C_2	D_3	E_2	F_{1b}	G_1	H_{2a}	I_1	J_1	K_7	L_2	M_5	N_3	O_{10}	P_1	Q_2	R_4	S_2
d	A_{5j}	B_3	C_2	D_2	E_1	F_{1a}	G_1	H_{2a}	I_1	J_1	K_3	L_2	M_5	—	O_{10}	P_1	Q_2	R_4	S_2
e	A_{5i}	B_3	C_2	D_2	E_1	F_{1a}	G_1	H_{2a}	I_1	J_1	K_4	L_2	M_2	N_1	O_{10}	P_1	Q_1	R_5	S_2
f	A_{1a}	B_4	C_3	D_2	E_3	F_{1b}	G_1	H_{2a}	I_1	J_1	K_5	L_4	M_1	—	O_1	P_1	Q_1	R_3	S_2
g.	A_2	B_1 B_4	C_2	D_2	E_3	F_2 F_3	G_1 G_3	H_{2a}	I_1 I_3	J_1 J_2	K_{10} K_7	L_2	M_3 M_4	N_2 N_8	O_1	P_1	Q_1	R_1	S_2
h	A_{1d}	B_2	C_2	D_2	E_3	F_{1b}	G_1	H_{2a}	I_1	J_1	K_8	L_3	M_2	N_7	O_1	P_1	Q_3	R_2	S_2
i	A_{1c}	B_1 B_4	C_2	D_2	E_3	F_2	G_1	H_{2a}	I_1	J_2	K_6 K_9	L_3	M_9	N_7	O_5	P_1	Q_1	R_6	S_2
j	A_{1c}	B_2	C_2	D_2	E_3	F_2	G_1	H_{2a}	I_1	J_1	K_8	L_4	—	N_7	—	P_1	Q_1	R_6	S_2
k	A_{1c}	B_4	C_2	D_2	E_3	F_2	G_1	H_{2a}	I_1	J_1	K_{11}	L_3	M_{10}	N_7	O_7	P_1	Q_1	R_3	S_2
l	A_{3h}	B_4	C_2	D_2	E_3	F_{1b} F_2	G_2	H_{2a}	I_1	J_1	K_{10} K_9 K_{13}	L_4	M_7 M_{10}	N_5	O_6 O_8	P_1	Q_1	R_3	S_2
m	A_{3g}	B_1	C_2	D_2	E_3	F_{1b}	G_1	H_{2a}	I_1	J_1	K_7	L_4	M_{10}	N_5	O_2	P_1	Q_1	R_3	S_2
n	A_{3h}	B_3	C_2	D_1	E_3	F_{1b}	G_1	H_{2a}	I_1	J_1	K_8	L_3	M_6	N_5	O_4	P_1	Q_3	R_2	S_2
o	A_{1b}	B_2	C_2	D_1	E_3	F_{1b}	G_1	H_{2a}	I_1	J_1	K_1	L_3	M_{11}	N_4	O_7	P_1	Q_1	R_5	S_2
p	A_4	B_3	C_2	D_4	E_3	F_{1b}	G_3	H_1	I_1	J_4	K_7	L_5	M_8	N_6	O_3	P_2	Q_1	R_3	S_2

Table 12. Coincidence-frequency of characters of the genera. a–p, representing the genera respectively same as in table 11.

(a) (b)	17										
(a) (c)	5	(b) (c)	4								
(a) (d)	6	(b) (d)	5	(c) (d)	15						
(a) (e)	9	(b) (e)	7	(c) (e)	12	(d) (e)	14				
(a) (f)	7	(b) (f)	6	(c) (f)	7	(d) (f)	8	(e) (f)	9		
(a) (g)	6	(b) (g)	6	(c) (g)	7	(d) (g)	7	(e) (g)	9	(f) (g)	10
(a) (h)	7	(b) (h)	6	(c) (h)	8	(d) (h)	9	(e) (h)	10	(f) (h)	11
(a) (i)	7	(b) (i)	6	(c) (i)	6	(d) (i)	7	(e) (i)	8	(f) (i)	10
(a) (j)	6	(b) (j)	5	(c) (j)	7	(d) (j)	8	(e) (j)	9	(f) (j)	11
(a) (k)	6	(b) (k)	5	(c) (k)	7	(d) (k)	8	(e) (k)	9	(f) (k)	12
(a) (l)	5	(b) (l)	4	(c) (l)	7	(d) (l)	8	(e) (l)	9	(f) (l)	12
(a) (m)	7	(b) (m)	6	(c) (m)	9	(d) (m)	9	(e) (m)	10	(f) (m)	12
(a) (n)	5	(b) (n)	4	(c) (n)	9	(d) (n)	9	(e) (n)	9	(f) (n)	8
(a) (o)	7	(b) (o)	6	(c) (o)	8	(d) (o)	8	(e) (o)	10	(f) (o)	10
(a) (p)	3	(b) (p)	2	(c) (p)	6	(d) (p)	5	(e) (p)	6	(f) (p)	6

(g) (h)	9										
(g) (i)	11	(h) (i)	11								
(g) (j)	10	(h) (j)	13	(i) (j)	13						
(g) (k)	11	(h) (k)	12	(i) (k)	14	(j) (k)	13				
(g) (l)	12	(h) (l)	9	(i) (l)	11	(j) (l)	11	(k) (l)	13		
(g) (m)	11	(h) (m)	10	(i) (m)	10	(j) (m)	11	(k) (m)	12	(l) (m)	15
(g) (n)	7	(h) (n)	13	(i) (n)	8	(j) (n)	9	(k) (n)	9	(l) (n)	10
(g) (o)	8	(h) (o)	12	(i) (o)	11	(j) (o)	11	(k) (o)	12	(l) (o)	9
(g) (p)	6	(h) (p)	5	(i) (p)	5	(j) (p)	5	(k) (p)	6	(l) (p)	7

(m) (n)	11				
(m) (o)	10	(n) (o)	11		
(m) (p)	8	(n) (p)	6	(o) (p)	6

latter two of these three characters are peculiar to this genus besides that the ophthalmopoda, which is the most signal feature of this genus, is outstandingly elongated, with cornea which is not wider than stalk. As seen in Table 12, the genus, *Miyadiella*, shows much affinity with *Penaeus*, *Trachypenaeus*, *Parapenaeopsis*, *Atypopenaeus*, *Metapenaeus*, *Penaeopsis*, and *Metapenaeopsis*. But it appears to be nearest to *Penaeus* judging from the condition of such orthogenetic apparatuses as petasma and appendix masculina.

The genus *Penaeus* is a large assemblage. The general body-form has been regarded not so much deviated from the ancestral form of Penaeids especially in feature of rostrum, carapace, twentieth body-segment, and telson, viz., Jurassic form, *Antrimpos speciosus*, which has been believed to represent the ancestor of the modern Penaeidae (BURKENROAD, 1936, p. 127), has a tooth on ventral border of rostrum as in species of *Penaeus japonicus*-series, adrostal carina not extending beyond epigastric tooth and no lateral spines of telson as in such Penaeids as ascribable to *Penaeus monodon*-series, and rather defined lateral carina on the twentieth body-somite as in all species of *Penaeus*. The animals of *Penaeus* are specialized in the following features, namely, carapace, third maxilliped, petasma, and thelycum are of Types, A_2, I_3, M_3 or M_4, and N_2 or N_8 respectively. But the general body-form and appendix masculina of this genus show intimate resemblance to those of *Miyadiella*. Thus it appears probable to the writer that the genus *Penaeus* diverged from the root common to the present genus and *Miyadiella*.

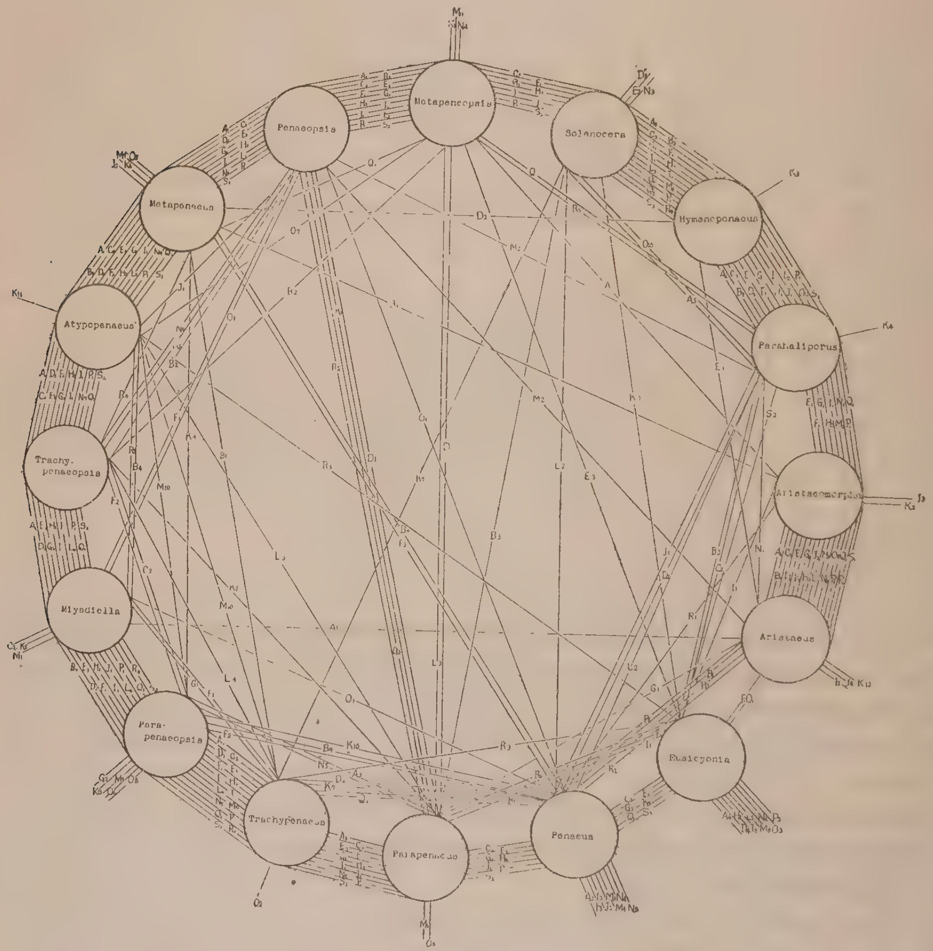
Metapenaeopsis
Solenocera
Hymenopenaeus
Parahaliporus
Aristaeomorpha
Aristaeus
Funchalia
Penaeus
Parapenaeus
Trachypenaeus
Parapenaeopsis
Miyadiella
Trachypenaeopsis
Atypopenaeus
Metapenaeus
Penaeopsis

Fig. 83. A_{1a}–A_{5k}, B_1–B_4, C_1–C_3, D_1–D_5, E_1–E_3, F_{1a}–F_3, G_1–G_3, H_1–H_{2b}, I_1–I_3, J_1–J_4, K_1–K_{13}, L_1–L_5, M_1–M_{11}, N_1–N_8, O_1–O_{10}, P_1 and P_2, Q_1–Q_3, R_1–R_6, and S_1 and S_2, representing the types of the following items respectively: carapace, telson, eye, antennule, mandible, maxillula, maxilla, first maxilliped, third maxilliped, arrangement of thoracic exopodites, arrangement of spines set on thoracic appendages, branchial arrangement, petasma, thelycum, appendix masculina, arrangement of pleonic endopodite, pterocardiac ossicle, zygocardiac ossicle, and prepyloric one.

However, the former is apparently more specialized than the latter in possession of the annexed features; carapace has sharply defined gastro-orbital, hepatic, cervical carinae, orbito-antennal groove, etc.; petasma consists of two endopodites which are united together with each other along median border, spout-like, and deeply channeled ventrally; distal piece of appendix masculina is furnished with setae; and third maxilliped of male undergoes much modification in feature.

Penaeopsis, which is a small group, is represented by *P. rectactus*, *P. serratus*, and *P. megalops* only, and defined by some traits, viz., hepatic carina is sigmoid in anterior half, and continuous to branchiostegal spine; petasma carries a pair of well calcified large pointed distolateral projections; distal piece of appendix masculina is scalelike, and semicircular in outline. Further, it is marked by having a well developed Parapenaeid spine on the basal antennular segment, although this character is shared by *Parapenaeus* and *Metapenaeopsis*. The genus under consideration is allied to *Trachypenaeopsis*, *Metapenaeus*, and *Atypopenaeus* in branchial arrangement and so forth, and related to *Penaeus* and *Miyadiella* in appendix masculina and petasma.

Metapenaeus, *Trachypenaeopsis* and *Atypopenaeus* form an offshoot of Penaeinae-stem, linked together with each other in the characters, viz., carapace is of Type–A_{1c}, ophthalmopoda Type–C_2, antennule Type–D_2, mandible Type–E_3, maxillula Type–F_2, maxilla Type–G_1, first maxilliped Type–H_{2a}, third maxilliped Type–I_1, thelycum Type–N_7, arrangement of pleonic endopodites Type–P_1, pterocardiac ossicle Type–Q_2, and prepyloric ossicle Type–S_2. *Metapenaeus*-branch is the largest among the three. *Metapenaeus* is defined from all other genera dealt with by the possession of the following traite: arrangement of the spines set on thoracic appendages posterior to second maxilliped is of Type–K_6 and K_9, petasma Type–N_8, and appendix masculina Type–O_5, but has no little genaelogical affinity with *Penaeus* and *Miyadiella* in petasma, thelycum, and appendix masculina, because each of which starts in metamorphosis from initial condition not very different from that of *Penaeus* and *Miyadiella* as mentioned already elswhere. *Trachypenaeopsis* greatly differs from both *Metapenaeus* and *Atypopenaeus*, since it has telson armed with movable and immovable dorso-lateral spines as is the case with that of *Metapenaeopsis* and *Penaeopsis*. The genus under consideration is, however, apparently nearer to *Metapenaeus* than to *Atypopenaeus*, in having zygocardiac ossicle which is furnished with teeth arranged in two longitudinal series as in that of *Metapenaeus*, no pleurobranchia on second thoracic somite, and a vestigial arthrobranchia on the seventh thoracic somite. In *Atypopenaeus*, arrangement of spines on thoracic appendages from third maxilliped to third pereiopod is of Type–K_{11}. By this character, *Atypopenaeus* may be separated from all other genera.

Trachypenaeus, *Parapenaeus*, and *Parapenaeopsis* again make an allied generic lump in having many characteristics common to them, viz., carapace belongs to Type–A_3, eye Type–C_2, mandible Type–E_3, first maxilliped Type–H_{2a}, third maxilliped Type–I_1, arrangement of exopodite of thoracic appendages Type–J_1 and that of pleonic endopodites Type–P_1, thelycum Type–N_5, and prepyloric ossicle Type–S_2. The most specialization of this generic lot may be found in carapace and petasma, the former is characterized by longitudinal and transverse sutures and the latter is provided with strikingly developed dorsolateral projections in *Trachypenaeus* and *Parapenaeopsis*, and with intricate distal structures in *Parapenaeus*. *Trachypenaeus* is decidedly recognizable from all other examined genera on basis of appendix masculina which is referable to Type–O_2. *Parapenaeopsis* is marked by possession of petasma which is of Type–M_7 or M_{10}, and appendix masculina ascribable to Type–O_6 or Type–O_8. It may be noticed herewith that the genus in question appears to be more closely related to *Trachypenaeus* than to *Parapenaeus* at least in the annexed respects which are common to *Parapenaeopsis* and *Trachypenaeus*, and unshared by *Parapenaeus*, viz., the Parapenaeid spine absent; petasma possesses a pair of outstanding disto-lateral projections; pleurobranchia is absent on seventh thoracic segment; pterocardiac ossicle is simply bar-shaped; and zygocardiac ossicle is of Type–R_3. The fact given in the following lines should be mentioned inasmuch as it is important for interpretation of phyletic relationship among *Trachypenaeus*, *Parapenaeopsis* and the genera of *Metapenaeus*-series. Regarding the petasma of *Trachypeneus* and *Parapenaeopsis*, a pair of its strikingly developed disto-lateral projections are unquestionably homologus with the rather developed trough-like outgrowths inserted at disto-lateral angles of petasma of *Metapenaeus* and *Atypopenaeus*. The genus *Parapenaeus* is defined from all other genera dealt with by the features of appendix masculina, petasma, and pterocardiac ossicle, which are of Type–O_4, Type–M_6, and Type–Q_3 respectively. The present genus is equal to *Metapenaeus* in possession of a pleuro-branchia on seventh thoracic segment. And appendix masculina of the genus in question intimately resembles that of *Metapenaeus* in general aspect, although it is not provided with a pit on the apical surface. Summarizing the facts given above, this lump is unquestionably more specialized than the *Metapenaeus*-lump at least in the build of carapace and petasma.

Metapenaeopsis, a large offshoot of Penaeinae-stem, which is as large as *Penaeus*, is greatly deviated from the typical form of Penaeinae-stem in the following points, viz., arrangement of spines laid down on thoracic appendages belongs to Type–K_1; male copulatory orgain is of Type–M_{11}; and thelycum is of Type–N_4. However, this genus exhibits intimate relationship to *Penaeopsis* in having shell clad with short setae, well developed Parapenaeid spine, and a pleurobranchia on seventh thoracic segment. Moreover, *Metapenaeopsis* is much related to *Metapenaeus* in branchial arrangement which is equal to that of the latter, though *Metapenaeopsis* bears a pair of immovable spines on dorso-lateral border of telson, appendix masculina referable to Type–O_7, zygocardiac ossicle which is of Type–R_5, etc., besides aforementioned distinctions which are particular to *Metapenaeopsis*. It appears to the writer, judging from the facts given above, that separation of this offshoot from common stock of Penaeinae may be not so earlier than that of *Penaeopsis*, *Metapenaeus*, and its congeners, and not very later than that of *Trachypenaeus* and its kins, with faster differentiation gaining such signal features noted already.

Solenocerinae-stem: The present stem comprises three closely allied genera, *Parahaliporus*, *Hymenopenaeus*, and *Solenocera*, and is characterized by appendix masculina which belongs to Type–O_{10}. This stem appears to be somewhat intermediate between Penaeinae-stem and Aristaeinae-stem. Because it is related to Penaeinae in possession of a podobranchia on the second thoracic somite alone, exopodite on all pereiopods, antennule without prosartema, and on the other hand, it is allied with Aristaeinae in the following important features, viz., petasma has a spatulate process on each ventral free edge of lateral lobe; distal piece of appendix masculina is made up of two scales; a pleurobranchia is present on the last thoracic segment; and a mastigobranchia occurs on third maxilliped,. However, Solenocerinae is very near to *Miyadiella* and *Penaeus* in having appendix masculina which is not only similar in feature to that of *Miyadiella* and *Penaeus* but also probably commences, in course of its transformation, from a state intimately resembling the apparatus of such two genera in question as in that of *Aristaeomorpha foliacea*. Moreover, Solenocerinae is connected with *Penaeus* in possession of a pleurobranchia on thoracic segments from third to eighth.

Of these three genera involved within Solenocerinae, *Parahaliporus* is characterized by having a suprahepatic spine, enormously elongated antennular flagella, and no prominent spines on third maxilliped and pereiopods. The genus in question is apparently more primitive than the two others, at least, in feature of petasma, pterocardiac ossicle, and zygocardiac one. Since the petasma is not provided with numerous setae on distal borders, and processes, *e. g.*, process-a, b, etc.; pterocardiac ossicle is simply bar-shaped; and zygocardiac is armed with a small number of teeth as is the case with that of *Metapenaeopsis*. The appendix masculina of *Parahaliporus* appears somewhat intermediate in general aspect between that of the two other genera of Solenocerinae and that of Aristaeinae.

In *Hymenopenaeus* the petasma closely resembles that of *Solenocera* in general feature, but the process–*a* is rather vestigial compared with that of *Solenocera*, and the antennular flagella are rather long as in those of Solenocera. It is worth mentioning that the antennular flagella of *Hymenopenaeus lucasii* demonstrate a transitional condition between those of *Paraliporus* and *Solenocera* as being about twice the length of carapace, somewhat compressed, especially in the lower flagellum which is shorter and thicker than the upper one, fringed with rather long and somewhat thickly set hairs along upper and lower borders. Whilst the pterocardiac ossicle is bifurcate at outer extremity, and zygocardiac one belongs to Type–R_4, as is the case with Solenocera. Thus *Hymenopenaeus* comes nearer to *Solenocera* than to *Parahaliporus*.

Solenocera appears to be more differentiated than *Parahaliporus* and *Hymenopenaeus* in shape of antennular flagella which are foliaceous and apposable to form so called respiratory tube.

Aristaeinae-stem: This stem embraces *Aristaeus* and *Aristaeomorpha*, and is well defined by the following six salient features which are

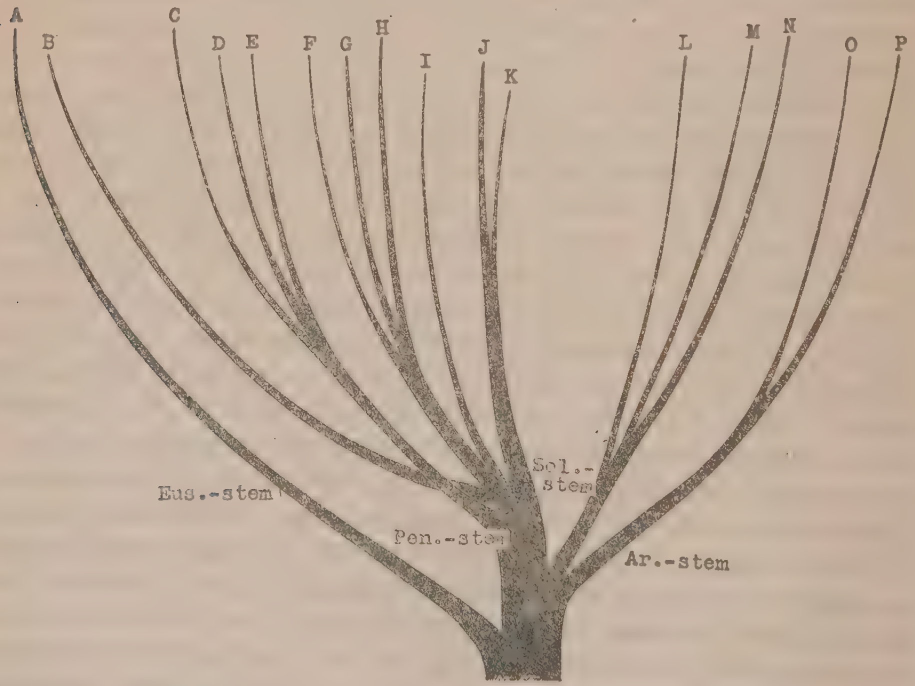

Fig. 84. Phylogenetical tree. *A*, *Eusicyonia*; *Ar.*, Aristaeinae; *B*, *Metapenaeopsis*; *C*, *Parapenaeus*; *D*, *Trachypenaeus*; *E*, *Parapenaeopsis*; *Eus.*, Eusicyoninae; *F*, *Atypopenaeus*; *G*, *Trachypenaeopsis*; *H*. *Metapenaeus*; *I*, *Penaeopsis*; *J*, *Penaeus*; *K*, *Miyadiella*; *L*, *Parahaliporus*; *M*, *Hymenopenaeus*; *N*, *Solenocera*; *O*, *Aristaeus*; *P*, *Aristaeomorpha*; *Pen.*, Penaeinae; *Sol.*, Solenocerinae.

common to such two genera but not shared by other genera at the writer's disposal, viz., ophthalmopoda is of Type–C_1; antennule Type–D_5; exopodal formula of thoracic appendages Type–J_3; appendix masculina Type–O_9; branchial arrangement Type–L_1; and prepyloric ossicle Type–S_1. As set forth already, Aristaeinae is closely related to Solenocerinae in many significant characters. To *Miyadiella* and *Penaeus*, Aristaeinae show close relationship not only in general feature of appendix masculina but also in palingenetic metamorphosis of the same appendage as given elswhere. Further, it is linked with *Penaeus* in possession of a pleurobranchia on the last thoracic segment. *Aristaeinae* are, however, greatly specialized from all other subfamilie dealt with in the annexed significant features, namely, antennule carries upper and lower flagella, the upper of which is vestigial, foliaceous, and inserted near proximal border instead of being attached to anterior extremity, the lower one is cylindrical and strikingly elongated; all pereiopods are destitute of exopodite; podobranchia is present on third maxilliped and first two or three pereiopods in addition to that set on the second maxilliped; prezygocardiac ossicle is remarkably elongated and furnished with many pointed setae on inner surface; and prepyloric ossicle is not armed with teeth along postero-lateral borders. Such being the case, the writer is inclined to consider that *Aristaeus* is more primitive than *Aristaeomorpha.*

Thus the genealogical relationship of the genera dealt with, at the present state of our knowledge, may be represented as given in Fig. 84.

The following 15 genera were not examined in the present investigation, viz., *Cerataspis*(1), *Hemipenaeus*(2), *Plesiopenaeus*(3) (=*Aristaeopenaeus*)(4), *Hepomadus*(5), *Benthesicymus*(6) (=*Benthoecetes*)(7), *Benthonectes*(8), *Bentheogennema*(9), *Gennadas*(10) (=*Amalopenaeus*)(11), *Halipo-*

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(1) STEBBING, 1893, pp. 220–221; CALMAN, 1909, pp. 279–282, and 310.

(2) BATE, 1881, p. 186; BOUVIER, 1908, p. 15; FAXON, 1895, p. 200; BURKENROAD, 1936, pp. 90–91.

(3) BATE, 1881, p. 188; FAXON, 1895, p. 199; ALCOCK, 1901, p. 35; BOUVIER, 1908, pp. 15 and 63; BURKENROAD, 1936, pp. 94–95.

(4) WOOD-MASON and ALCOCK, 1891. pp. 282–283.

(5) BATE, 1881, p. 189; BURKENROAD, 1936, p. 86.

(6) BATE, 1881, p. 190; 1888, p. 326; FAXON, 1895, p. 203; ALCOCK, 1901, p. 43; BOUVIER, 1908, p. 16; SCHMITT, 1921, p. 22; BURKENROAD, 1936, p. 23.

(7) SMITH, 1884, pp. 391–396.

(8) BOUVIER, 1908, p. 15.

(9) BURKENROAD, 1936, p. 56.

(10) BATE, 1881, p. 191; BOUVIER, 1908, p. 24; KEMP, 1909, p. 718, SCHMITT, 1921, p. 23; BURKENROAD, 1936, p. 59.

(11) SMITH, 1884, p. 399.

rus(12), *Funchalia*(13) (=*Hemipenaeopsis*, and *Grimaldiella*)(14), *Artemesia*(15), *Heteropenaeus*(16), *Macropetasma*(17), *Protrachypenaeus*(18), and *Xiphopenaeus*(19). But interrelationship among these genera and those represented in my material may be discussed to certain extent by reference to literatures.

Cerataspis seems most primitive among Penaeidae when viewed from the status of stomodaeal apparatus (CALMAN, *op. cit.*), since cardiac, pterocardiac, and zygocardiac ossicles appear not yet differentiated.

Hemipenaeus, *Plesiopenaeus*, *Hepomadus*, *Benthesicymus*, *Benthonectes*, *Benthogennema*, and *Gennadas* belong to Aristaeinae, and are characterized by having no or quite vestigial prosartema, first segment of mandibular palp much longer than the second, and a podobranchia on each of the first two or three pereiopods. The former three are closely related to *Aristaeus* and *Arisaeomorpha* in the annexed characters: upper antennular flagellum is extremely short, and lower ramus is long; basal segment of mandibular palp is much longer than second, compressed and broad. More closely allied to *Aristaeus* than to *Aristaeomorpha* are: *Hemipenaeus* and *Plesiopenaeus*, but the latter is distinguished from the former in bearing a podobranchia on sixth thoracic somite and a mastigobranchia on the seventh, since common to *Hemipenaeus*, *Plesiopenaeus*, and *Aristaeus*, but not shared by *Aristaeomorpha*-series are such characters as carapace is provided with no hepatic spine, and rostrum armed with 3 (rarely 2–4) teeth dorsally. *Hepomadus* is not furnished with podobranchia on sixth thoracic somite, and carries three teeth on upper border of rostrum as is the case with *Aristaeus* and *Hemipenaeus*. But this genus is linked with *Aristaeomorpha* in possession of hepatic spine.

Benthesicymus, *Benthonectes*, *Bentheogennema*, and *Gennadas*, have antennule with which both flagella are long. In this feature, these genera are much related to *Hymenopenaeus*, *Haliporus*, and *Parahaliporus*. *Benthesicymus* and *Benthonectes* are very intimately allied genera, the latter is according to BOUVIER (1908, p. 15), merely recognizable from the former by having filiform fourth and fifth pereiopods. On the authority of BURKENROAD (1936), *Gennadas* greatly differs from *Benthesicymus* and *Bentheogennema* in arrangement of podobranchia, but

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(12) BATE, 1881, p. 185; BURKENROAD, 1936 b, pp. 100–102.

(13) JOHNSON, 1867, pp. 895–901; BOUVIER, 1908, p. 91; BURKENROAD, 1936, pp. 126–128.

(14) BOUVIER, 1908, p. 91.

(15) BATE, 1888, pp. 280–281; BOUVIER, 1908, p. 76.

(16) DE MAN, 1896, pp. 111–113; 1898, p. 684; ALCOCK, 1906, pp. 5 and 16; BOUVIER, 1908, p. 76; BURKENROAD, 1934 a, p. 77.

(17) STEBBING, 1914, p. 22.

(18) BURKENROAD, 1934 b, p. 43.

(19) ALCOCK, 1906, p. 52; BURKENROAD, 1934 a, pp. 102–103.

it appears more related to *Bentheogennema* than to *Benthesicymus* in features of exopodite of first maxilliped, abdomen, and telson. A podobranchia is present on first and second thoracic segments in *Gennadas*, whilst on each of the segment from first to sixth in *Benthesicymus* and *Bentheogennema*. Abdomen is carinated dorsally in addition to twentieth joint, and telson is provided with four pairs of mobile dorso-lateral spinules and usually pointed at tip in *Benthesicymus*. On the other hand, pleon is carinated dorsally in twentieth segment only, and telson is armed with a pair of movable dorso-lateral spinules, not acuminate at apex in *Bentheogennema* and *Gennadas*. Exopodite of first maxilliped is constricted and segmented anteriorly as in that of *Aristaeus* and *Aristaeomorpha* in *Benthesicymus*, but the exopodite is not shaped in such manners in the other two genera in question.

Haliporus is so similar to *Hymenopenaeus* in general feature as belived to be identical with the latter by many prior investigators. But the former is easily discernible from the latter in having short prosartema and podobranchiae behind second thoracic segment (BURKENROAD, 1936, p. 103). Of these two genera of Solenocerinae, *Haliporus* is more closely related to Aristaeinae in such primitive features as podobranchiae existing on thoracic appendages posterior to second maxilliped.

Funchalia is undoubtedly a primitive genus. In discussion of interrelationship of Penaeidae, BOUVIER (1908) assigned to this genus a position close to Solenocerinae. FUNCHALIA seems, however, nearest to *Penaeus* as already stated by BURKENROAD (*op. cit.*), since the following significant features are common to the present genus and the genus, *Penaeus*, viz., a pleurobranchia lies on the last thoracic segment; epipodite strongly forked at apex; an epipodite is attached to third maxilliped; and maxillulary palp much elongated. It should be noticed that maxilla of *Funchalia* has three gnathobasic laciniae as in *Eusicyonia*, and *Penaeus vannamei*. Petasma of the genus under consideration is rather differentiated as in that of *Aristaeus* and *Aristaeomorpha*, but somewhat more intricated than that of *Miyadiella*. According to BURKENROAD (1936, p. 128), this masculin organ is provided with a pair of disto-ventral projections. In this character, *Funchalia* may be regarded to conjoin genealogically with Solenocerinae and Aristaeinae.

Heteropenaeus established by DE MAN (1896) approaches *Penaeus* in the branchial and thoracic exopodal arrangements which are the same as those of the latter genus (ALCOCK, 1906, p. 16, and BURKENROAD, 1934 a, p. 77). Besides, petasma is symmetrical and simple as in that of *Penaeus*. But it is genus-specific that first pereiopod of adult male is enormously elongated.

Artemesia is related to *Metapenaeus* and *Metapenaeopsis* in lacking pleurobranchia on eighth thoracic segment, and mastigobranchia on the last two thoracic segments, as well as in having two arthrobranchiae on the penult thoracic segment, podobranchia on the second and epipodite on the first three pereipods, although it differs in possession of pleurobranchia anterior to third thoracic somite, and a functional anterior arthrobranchia on the seventh instead of being vestigial, simply bar-shaped. The character that all pereiopods from first to fourth are destitute of exopodite indicates *Artemesia* is allied to *Aristaeus*, *Aristaeomorpha* and *Eusicyonia.* Moreover, the male copulatory organ of *Artemesia* seems, according to BATE's illustration (1888, p. 40), resembling that of *Metapenaeus* in essential feature.

The genus *Protrachypenaeus*, is nearest to *Trachypenaeus*, splitable from the latter in having no exopodite on second maxilliped, more number (eight or more pairs) of movable spinules on dorso-lateral rims of telson, and posterior two pairs of pereiopods flagelliform. The first character given above is paralleled by *Artemesia*, *Macropetasma*, and *Eusicyonia.*

Macropetasma is a genus of Penaeinae, and related to *Atypopopenaeus*, *Metapenaeus*, *Metapenaeopsis*, *Penaeopsis*, *Trachypenaeus*, *Trachypenaeopsis* and *Miyadiella*, in having an epipodite on each of the first three pereiopods. It shows an intimate relation with *Eusicyonia* as exopodite is absent on posterior two maxillipeds and all thoracic limbs, and as a mastigobranchia is set on each of first three pereiopods. The distal joint of mandibular palp narrows toward tip as in that of Solenocerinae and Aristaeinae. The fourth and fifth pereiopods are very slender. This character is only paralleled by two genera, *Artemesia*, *Benthonectes*, and some species of *Benthesicymus* among Penaeidae. The petasma is peculiar, with "long style-like terminals". But these appendages seem to be homologous with those of *Parapenaeopsis.*

Xiphopenaeus is apparently very near to *Parapenaeus* or *Parapenaeopsis* as it has longitudinal and transverse sutures on carapace, but the longitudinal one is not prolonged to posterior border of carapace as in that of *Parapenaeopsis.* Maxillulary palp is short and unsegmented as is the case with that of *Parapenaeus* and that of some forms of *Parapenaeopsis.* However, it differs from the two genera, *Parapenaeus* and *Parapenaeopsis* in the annexed respect: one of antennular flagella is very long. All thoracic appendages of this genus are in possession of exopodite as in those of Solenocerinae and most genera of Penaeidea.

B. PHYLOGENETICAL POSITION OF THE TRIBE PENAEIDEA

Credit is due to ORTMANN (1896) and BORRADAILE (1907) for giving substantial riews on the phylogeny of the Penaeidea in connection with the Stenopidea and Caridea. The first author regards the Eucyphidea (=Caridea) as the lowest of the three, the Penaeidea lower than, but nearer to, the Stenopidea in degree of evolution. But the second investigator just reverses the above mentioned evolutional scale, i.e., he puts the Caridea at the top and the Stenopidea at the base, whilst the Penaeidea, placed superior to the Stenopidea, is looked upon by him as more closely allied to the Caridea than to the Stenopidea. In spite of such discrepancy, the two scholars agree in the belief that the Stenopidea was separated from the common stock of the Natantia earlier than the Caridea.

The meagreness of our present knowledge does not permit one to decide between these two alternatives. Yet mention should be made of some facts which would suggest, so far as possible, phylogenetical relationship of the groups in question. The stomodaeal apparatus which has proved indispensable for discrimination of species and genera of the Penaeidea appears also usefull for general consideration. The Stenopidea stands in this respect nearer to lower representatives of Reptantia than to the Penaeidea although it shows much similarity to Sergestidae in details of morphological facies of the alimetary organ. This fact, it should be borne in mind, does not support either of the above-mentioned two opinions.

An evidence which leads one to accept primitiveness of Penaeidea lies in the persistence of nauplius or metanauplius larvae in the ontogeny of this group whereas zoea larvae hatch out correspondingly in the Caridea and Stenopidea.

Branchial structures, on the other hand, rather clearly point to the conclusion that the Penaeidea is the lowest, the Stenopidea higher, and Caridea highest group in genealogical steps since dendroid, trichous, and foliaceous branchiae are respectively found in these. However, the number and arrangement of branchiae do not tell anything about the phylogeny, but may be taken as particular phases of adaptation which took place irrespective of lines of descent of these crustaceans.

We have reason to believe that egg-fixation to the underside of the abdomen took place later than egg-freeing in the water as the evolution went on. The Penaeidea should be, therefore, the most primitive of the three inasmuch as the majority of the Penaeidea, with only exception of the aberrant crustacean, *Lucifer*, lay their eggs floating in the water.

Caution should be taken in weighing relative importance of various traits as revealed by these groups. It goes without saying that the antennal scale, for instance, was simultaneously developed with swimming habit, and it can not be a weapon for deciding a question as to whether or not the elaboration of this apparatus relates anything of evolutional level. Similar argument may be set forth in estimating the phylogenetical value of the petasma. Possession of petasma may be considered a phase of either primitiveness or higher specialization.

To sum up, the Penaeidea is the most primitive of all the three groups and the best evidence for this is obtained in the ontogeny, viz., in the hatching of the simplest larval form.

V. Systematic Part

Family ***Penaeidae***, BATE (emend)

Penaeidae, BATE, 1888, pp. 220-229; RATHBUN, 1902 (for 1900), p. 100; BORRADAILE, 1907, p. 470; BOUVIER, 1908, pp. 9-13; VILLALUZ and ARRIOLA, 1938, p. 37.
Peneidae, ALCOCK, 1901, pp. 10-12; SCHMITT, 1921, p. 20.

Body somewhat or considerably compressed. Rostrum usually well developed, laterally compressed and armed with teeth. Eye moderote or greatly elongated. Antennule carries two flagella and stylocerite on basal outer margin of the first peduncular segment. Antennal scale depressed, broad. Mandible bearing both molar and incisor processes, but they are fused at posterior end; palp foliaceous, two-segmented. Maxillula consists of three laciniae, and endopodite unsegmented or segmented. Maxilla foliaceous with inner two, anterior and posterior, endites both of which are typically bifid but the latter variable in configuration. First maxilliped carries a slender endopodite unsegmented or jointed into five. Second and third maxillipeds pediform, seven-segmented. First to third pereiopods chelate, gradually increasing in length backwards. Last two legs bearing simply pointed dactylus. Petasma and appendix masculina well developed. Thelycum usually well developed.

Branchiae numerous. Arthrobranchiae in a double series.

Stomodaeal ossifications well developed. Cardiac plate provided on inner surface with spinules arranged in a longitudinal row. Zygocardiac ossicle armed with teeth on inner surface.

The emendation has been done mostly on the following items: eyes, branchiae and stomodaeal sclerites. The eyes of Penaeidae have been known to be ordinary in configuration. But those in *Miyadiella*, gen. nov., strikingly elongated resembling those of the shrimps involved in genera, *Ogyrides*, *Sicyonella* and *Acetes*. ALCOCK (1901), and others believed that the arthrobranchiae of Eusicyoninae are arranged in a single series. It is however, affirmed by the present author that the branchiae are laid down in a double series, likewise in other subfamilies of the family as pointed out by BURKENROAD (1934, p. 119). For the stomodaeal apparatus, no attention has hitherto been paid by previous investigators from view point of taxonomy.

The present family is closely related to the family Sergestidae, but it is easily discernible from the latter by having the following characters:—(1) the last two pairs of pereiopods are well developed (in Sergestidae, they are reduced in size; one or both pairs are sometimes lacking), and (2) the branchiae are numerous instead of being never more than eight on each side or sometimes absent.

The Penaeidae may be classified into five subfamilies, Cerataspinae (STEBBING, 1893, p. 220; BORRADAILE, 1907, p. 470; CALMAN, 1909, p. 310), Aristaeinae, Solenocerinae, Penaeinae, and Eusicyoninae. Putting aside Cerataspinae, which is not represented in the present material, other four subfamilies are recognizable as given in the following key.

Key to the subfamilies

A_1 Pleurobranchiae are seven and podobranchiae are more than one in number; upper antennular flagellum inserted near posterior border of third antennular segment, strikingly shorter than other ....**Aristaeinae.**

A_2 Pleurobranchiae are two to six, and podobranchiae is usually one in number, upper antennular flagallum, subequal to the lower one attached to apex of third antennular segment

- B_1 Cervical groove reaches or almost reaches to dorsum; post-orbital spine present; distal piece of appendix masculina made up of two scales ....**Solenocerinae.**
- B_2 Cervical groove extends at last to about half-way toward dorsum; post-orbital spine absent; distal piece of appendix masculina single, usually thickened
  - C_1 Prosartema present; exopodite exists on thoracic appendages posterior to first maxilliped; pleonic appendages provided with endopodite; pleurobranchiae present on thoracic segments posterior to the third segment ....**Penaeinae.**
  - C_2 Prosartema absent; exopodite absent on thoracic appendages from second maxllliped to the last pereiopod; pleopods without endopodite; pleurobranchiae absent on thoracic segments posterior to the third segment ....**Eusicyoninae.**

Subfamily *Aristaeinae* ALCOCK

Aristaeinae, ALCOCK, 1901, pp. 12, 27-28, DE MAN, 1911, p. 13.
Aristeinae, BOUVIER, 1908, pp. 13-16.

Aristaeomorpha rostridentata (BATE) and *Aristaeus japonicus* YOKOYA, have been reported from Japanese waters by PARISI (1919) and YOKOYA (1933). But both the species may be synonymous with *Aristaeomorpha foliacea** (RISSSO), as given later on.

The material on hand is referable to two species representing two genera, *Aristaeus* and *Aristaeomorpha*. Remarkably enough, the following traits are found common and peculiar to tnese genera:—(1) the appendix masculina is of the type–O_9, and (2) the prepyloric ossicle has no spinous armatures along posterolateral margins.

The genera are recognizable as given in the following key.

Key to the genera of Aristaeinae

A_1 Rostrum three-toothed dorsally; hepatic spine lacking; podobranchia absent on sixth thoracic somite; mastigobranchia absent on seventh thoracic somite ....*Aristaeus.*

A₂ Rostrum armed with many teeth on upper border; hepatic spine present; podobranchia exists on sixth thoracic somite; mastigobranchia present on seventh thoracic somite. ....*Aristaeomorpha.*

Genus *Aristaeus* DUVERNOY

Aristeus, BATE, 1888, pp. 309-311; WOOD-MASON, 1891, p. 279; BOUVIER, 1908, pp. 15 and 69; DE MAN, 1911, p. 27.

Aristaeus virilis (BATE)

(Figs. 1, *B*; 6, *A*; 8, *Y*; 11, *B*; 13, *C* and *D*; 14, *F*; 19, *A*; 23. *E* and *F*; 36, *G* and *J*; 44, *D*; 65, *A* and *B*; 69, *D-G*; 72, *B* and *H*; 78; *E*; 85; 86).

Aristaeus virilis, WOOD-MASON, 1891, p. 279; ALCOCK, 1901, p. 30; BOUVIER, 1908, p. 70; DE MAN, pp. 27-29, pl. 2, fig. 6.

Hemipenaeus virilis, BATE, 1881, p. 187; 1888, p. 303, pl. 44, fig. 4.

Hemipenaeus tomentosus, BATE, 1881, p. 189; 1888, p. 307, pl. 49, figs. 2 and 3, pl. 50.

Carapace belongs to Type–A_{1d}. Post-rostral carina rather developed, extends a little beyond the middle of carapace. Cervical carina more or less defined in its lower portion. Hepatic (in about anterior half) and pterygostomian carinae rather noticeable of which the former continues to branchiostegal spine. Hepatic and branchiocardiac grooves rather developed. Antennal and branchiostegal spines found to exist, the latter much larger than the other. Pteryostomian margin angulated at an angle of about 150°. Abdomen more strongly laterally compressed in posterior three segments than in anterior three ones, carinated along mid-dorsal line posterior to about middle of fourth segment; the carina of each segment ends in a sharp minute spine pointing backward. Telson gradually tapers into acuminate tip, a little more than three times as long as wide measured at the broadest region, provided with a rather shallow depression along dorsal median line and proximal three pairs of movable and the rearmost pair of immovable spinules, movable ones are placed at three-fifths, seven-ninths and eight-ninths respectively. Mandible is of Type–E_1; palp markedly deviated from typical form, two-segmented; basal segment gets distally somewhat wider, a little less than twice the width measured at the widest region; the last segment deltoid with rounded apex, smaller than basal one, about 0.8 times the length of the other (Fig. 8, *Y*). Maxillula is of Type–F_{1a}; endopodite unsegmented, gradually diminishes in size toward rounded apex, and considerably curves forwards at about two-thirds. Maxilla is of Type–G_1, closely resembles that of *A. antennatus* (BOUVIER, 1908, pl. 12, fig. 2). First maxilliped belongs to Type–H_{2b}; endopodite segmented into five, proportions of length to that of the last joint 3 in first, 0.5 in second, 0.9 in third, and 1.8 in fourth; inner margin of basal segment markedly notched in distal about one-third, and furnished with several stout setae at about two-thirds; penult segment more or less broader than others except for basal one, ca. 3.5 times the width; exopodite narrow, about 6 times as long as wide, furnished on inner distal margin with a short whip-like outgrowth projected forwards measuring about two-sevenths the length of the lamellate portion (Fig. 11, *B*). Second maxilliped pediform, seven-jointed; ratios of length to that of the last segment 2.8 in merus, 1.1 in carpus and propodus; meropodite subrectangular in outline with parallel sides, about thrice as long as wide, lamellar in inner about half; carpus and propodus subequal in size, about half times the width of meropodite; dactylus distally decreases in size toward bluntly pointed apex, which bears several prominent setae. Third maxilliped pediform, slightly shorter than first pereiopod, and reaches to far end of antennular peduncle; penult segment of male provided with a tuft of rather long hairs on upper extremity; the last segment of both sexes considerably excavated in ventral proximal portion, and somewhat triangular in profile in the rest (Fig. 13, *C* and *D*).

Pereiopods successively increase in length posteriorly as delineated in Fig. 85. First and third pereiopods extend to apex of antennal scale. Fourth furnished on inner posterior surface of coxa with considerably developed process, inner margin of which comes into contact with outer fringe of transverse plate laid down on posterior edge of penult thoracic sternite. Fifth surmounts distal end of antennal scale by about half of dactylus.

Petasma is of Type-M_2, provided near the middle of free lateral margin with a large spatulate process which is produced as far forwards as seven-eights of the appartus, trancate at apex, about six times as long as wide (Fig. 36, *G* and *J*). Appendix masculina well developed, belongs to Type-O_9; distal inner scale shield-like in outline, rather narrow, rounded at apex with several setae, about twice as long as wide, flat on inner surface, markedly decreases in width in distal about one-third, since its anterior margin suddenly curves backwards at an angle of about 140° at ca. two-thirds and posterior margin slightly convex (Fig. 65, *A* and *B*); distal outer scale subtriangular, about two and half times as long as wide, much smaller and shorter (ca. three-fourths) than the inner scale, devoid of hairs along anterior margin but fringed with rather long hairs along posterior margin (Fig. 65, *B*).

Thelycum is of Type-N_1, made up of a prominent transverse plate, a barely marked pyramidal upheaval, and a pair of lateral processes. Transverse plate inserted on posterior margin of penult thoracic sternite, directed antero-ventrally, rounded at apex, slightly concave on posterior surface. Pyramidal upheaval located at center of the last thoracic sternite, having two surfaces anteriorly. Lateral processes compressed, with sharply defind ventral margin, pointed anteriorly, directed forward, placed close to inner bases of fifth pereiopods. Median protuberance of posterior ridge of eighth thoracic sternite rather prominent, rounded at apex, directed antero-ventrally (Fig. 44, *D*).

Cardiac ossicle well defined. Pterocardiac ossicle bar-shaped, gradually decreases in width toward outer tip, somewhat curved forwards in outer subterminal portion. Cardiac plate partly calcified, armed on inner surface with a longitudinal series of 18–21 sharply pointed spinules (Fig. 78, *E*). Prezygocardiac very slender, nearly stretching to anterior end of cardiac plate, furnished with rather thickly set acute setae. Zygocardiac carries on inner surface a longitudinal row of several teeth, of which the foremost one is the largest with pointed rpex lying near its anterior margin, but the rest with blunt tip gradually decrease in size posteriorly, inner postero-inferior region covered with many rather sparsely set setae (Fig. 78, *E*). Urocardiac well defined especially in anterior portion, with broadly rounded apex, and a large bluntly pointed process directed sidewise on each antero-lateral margin (Fig. 72, *B*). Prepyloric ossicle simple, with large rounded apex directed strongly forward and no lateral armatures at all, but clad with rather sparsely set short setae directed antero-ventrally on lower surface (Fig. 72, *B* and *H*). Pyloric fold, supra-ampullary ridge, preampullary and pyloric plates are well marked.

The description given above is based on a male, 146 mm long (45.6 mm in carapace-length) and a female, 153 mm long (47.8 mm). Besides, 3 males, 85–113 mm long (25–34 mm) and 19 females, 81–165 mm in length (23.6–52.0 mm) were also examined.

Locality: Kumanonada (350–450 m), off Owase, Mie Pref.: Heta (ca. 400 m), Siduoka Pref.

Distribution: Near the Philippine Islands, New Hebrides (BATE); Andaman Sea (ALCOCK); Flores Sea (521 m), Strait of Makassar (450 m), Halmahera Sea (798 m), Seram Sea (567 m), off Saleyer (462 m), Near Kei-Islands (560 m), Bali Sea (538 m) (DE MAN).

Note: The rostrum is considerably variable in configuration. The distal about half varies in elevation from horizontal to about 30°. As shown in Fig. 1, *B*, ratio of the length of rostrum to that of carapace inversely decreases with increase of the carapecial length as is the case with *Aristaeomorpha foliacea*, *Parapenaeopsis hardwickii*, *Penaeus monodon*, *P. semisulcatus*, *P. japonicus*, *P. latisulcatus*, *Metapenaeus monoceros*, *M. joyneri*, *Eusicyonia cristata*, *Penaeopsis lamellatus* and *Parahaliporus sibogae*. The ratio is larger than 1 in most cases of younger specimens, less than 30 mm in carapace-length (about 100 mm in body-length), but smaller than 1 in larger ones than those given above. Spines beset on the upper border are 3 in number without exception. The rearmost one is always located on carapace somewhat posterior to the post-orbital margin, and the foremost one about above the extremity of the basal segment of antennular peduncle, irrespective of sex and age.

Growth of all the pereiopods and each of the distal four segments of all the chelipeds is proportional to that of the carapace, so far as the present investigation goes (Fig. 86, *B–H*). The growth-trends run almost parallel whan plotted with merus and carpus of the first and third chelipeds, and with palm and movable finger of the third cheliped. Ratios in length to carapace are follows:—

	Total length	Merus	carpus	Palm	Finger
First pereiopod	1.1	0.34	0.25	0.12	0.22
Second „	1.3	0.35	0.35	0.15	0.23
Third „	1.4	0.40	0.46	0.17	0.24
Fourth „	1.7	—	—	—	—
Fifth „	1.8	—	—	—	—

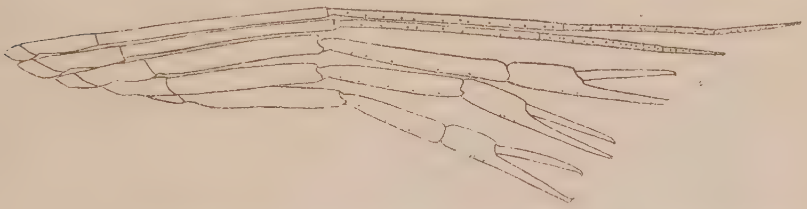

Fig. 85. Pereiopods from first to fifth of a male of *Aristaeus virilis*, especially showing the distribution of luminous organs, ×2.

A number of small spot-like luminous organs are present on the ventro-lateral surface of both carpus and palm of all the chelipeds and all the three distal segments of the last two pereiopods, but never found on the fingers of the chelae as illustrated in Fig. 85. This organ is scarlet in fresh specimens. As shown in Table 13, the number is considerably variable irrespective of sex, age, as well as right and left, ranging 6–17 in carpus, 1–15 in propodus, and 1–10 in dactylus.

With regard to the branchiae, the following facts should be stated here. In the present specimens, each pleurobranchia in front of the fourteenth body-somite is provided with a number of pinnules more than three or four (ALCOCK, 6901, p. 30), as was already pointed out by DE MAN (1911, p. 28). There is a tendency that both the size of the branchiae and the number of the pinnules progressively decrease forwards. In a male specimen, 146 mm in length, the number of the tiny bodies runs as follows: 8 on the right side (r), 6 on the left side (1) in the branchia of the somite IX; X, 11 (r), 12 (1); XI, 14 (r), 14 (1); XII, 16 (r), 15 (1); XIII, 19 (r), 20 (1). It has been known by DE MAN (op. cit., pp. 28 and 29) that the pinnules of the thirteenth somite vary 10–15

Table 13. Number of luminous organs on pereiopods. BL, body-length; c, carpopodite; CL, carapace-length; d, dactylopodite; p, propodite.

Sex	(in mm) BL	CL	Right side															Left side														
			First leg			Second leg			Third leg			Fourth leg			Fifth leg			First leg			Second leg			Third leg			Fourth leg			Fifth leg		
			c	p	d	c	p	d	c	p	d	c	p	d	c	p	d	c	p	d	c	p	d	c	p	d	c	p	d	c	p	d
♀	81.0	24.0	7	3	0	—	—	—	5	2	0	—	—	—	—	—	—	8	3	0	—	—	—	—	—	—	—	—	—	8	12	8
,,	84.5	26.0	8	4	0	6	2	0	6	2	0	12	12	4	—	—	—	7	2	0	7	3	0	5	2	0	—	—	—	—	—	—
♂	85.0	25.0	9	3	0	6	2	0	5	2	0	10	10	—	9	14	5	7	2	0	8	2	0	6	2	0	—	—	—	—	—	—
♀	87.0	27.0	8	2	0	6	2	0	4	1	0	—	—	—	—	—	—	8	2	0	—	—	—	5	2	0	—	—	—	—	—	—
♂	92.0	27.0	6	3	0	6	3	0	5	3	0	8	15	4	13	13	8	8	3	0	5	3	0	5	3	0	14	11	3	12	15	6
♀	96.0	28.0	7	2	0	6	2	0	—	—	—	—	—	—	—	—	—	7	2	0	5	2	0	5	2	0	8	10	4	9	10	8
♂	98.0	29.0	6	3	0	5	3	0	6	3	0	—	—	—	—	—	—	7	3	0	6	3	0	5	—	—	12	11	4	—	—	—
♀	105.0	32.0	8	2	0	5	2	0	—	—	—	8	—	—	10	—	—	8	2	0	6	2	0	4	2	0	11	9	1	10	11	8
,,	108.0	34.0	7	3	0	6	3	0	—	—	—	—	—	—	—	—	—	7	3	0	—	—	—	5	3	0	11	13	8	12	14	10
,,	110.0	33.5	8	3	0	5	3	0	6	2	0	—	—	—	11	14	8	7	3	0	5	3	0	4	2	0	9	11	—	—	—	—
♂	111.0	35.0	8	4	0	7	4	0	6	3	0	—	—	—	11	12	4	9	4	0	6	3	0	6	3	0	—	—	—	12	13	8
♀	112.0	34.0	8	3	0	7	2	0	5	2	0	—	—	—	9	9	4	9	2	0	6	3	0	6	3	0	11	9	1	10	9	6
,,	113.0	34.5	7	3	0	12	0	0	13	0	0	14	—	—	—	—	—	10	1	0	10	2	1	9	2	0	17	12	5	16	14	6
,,	118.0	35.5	7	3	0	6	3	0	5	2	0	11	—	—	—	—	—	7	3	0	—	—	—	6	—	—	12	11	5	13	15	8
,,	142.0	48.0	8	3	0	6	3	0	—	—	—	13	11	1	—	—	—	7	2	0	6	1	0	9	1	0	13	12	3	13	11	7
,,	151.0	48.0	8	3	0	9	2	0	8	3	0	11	11	3	—	—	—	8	3	0	7	3	0	6	2	0	11	13	4	10	13	4

in number. They are found, however, to range 11–20 in number in our specimens, except for a specimen bearing a couple of Bopyrid isopods in its branchial chamber. The number of bifurcate and more branched pinnules also shows some extent of variation as given in Table 14.

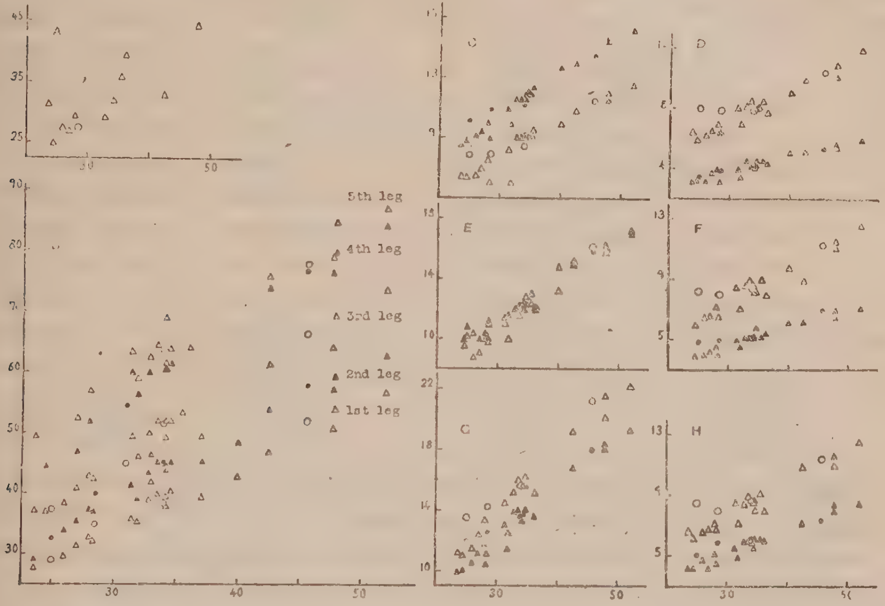

Fig. 86. Showing dimensions (in mm) of rostrum (A), pereiopods from first to fifth (B), merus and carpus of first leg (C), palm and finger of first leg (D), merus and carpus of second leg (E), palm and finger of second leg (F), merus and carpus of third leg (G), and palm and finger of third leg (H) of *Aristaeus virilis* in relation to carapace-length. Circles, male, triangles, female. Solid marks, second and third limbs, merus and palm. Soft marks, first, third and fifth legs, carpus and finger.

Sexual differences are observed in the antennal scale and the third maxilliped besides the copulatory organs. In male, the antennal scale is considerably thickened in some terminal portion as stated by BATE (*op. cit.*), and the penult segment of the third maxilliped is furnished with a tuft of hairs at distal upper end (Fig. 13, *C* and *D*). The last segments of both the second and third maxillipeds of our specimens are not sexually dimorphic. But it is not the case with *Aristaeus antennatus* RISSO (BOUVIER, *op. cit.*, pp. 70–72).

As regards petasma, the metamorphosis has been stated already elsewhere in this paper. It is a matter of interest from standpoint of phylogeny that some species of *Plesiopenaeus*, for instance, *P. coruscaus* WOOD-MASON (BURKENROAD, 1936, p. 99, fig. 61) have a petatasma that very closely resembles that of present species.

The spines found in pair on the hindomost thoracic sternite close to

Table 14. Showing body-length (BL), carapace-length (CL), and number of pinnules of pleurobranchia of somite XIII (NP). Numerals given in brackets indicate the number of branching pinnules. B, with a couple of Bopyrid isopods in branchial chamber.

Sex	Length in mm		NP		Sex	Length in mm		NP	
	BL	CL	Right	Left		BL	CL	Right	Left
♀	—	52.0	11(0)	13(3)	♀	104.0	31.4	16(0)	14(2)
,,	153.0	47.8	12(0)	12(0)	,,	99.2	31.9	16(15)	17(15)
♂	146.0	45.6	15(7)	16(6)	♂	97.0	28.5	15(4)	16(5)
♀	128.5	42.5	17(2)	15(4)	,,	85.0	25.0	15(13)	15(11)
,,	143.0	47.7	12(6)	13(5)	♀	—	28.3	14(0)	14(7)
,,	126.1	40.0	14(11)	13(10)	,,	113.5	34.6	16(7)	15(6)
,,	116.0	36.1	17(15)	18(17)	,,	96.0	28.0	18(8)	17(4)
,,	112.0	34.2	15(6)	16(4)	,,	83.5	24.5	13(0)	16(0)
,, B	107.5	32.8	3(0)	5(0)	,,	63.9	27.0	15(3)	15(4)
♂	—	34.0	20(18)	17(17)	,,	117.5	35.5	14(12)	16(8)
♀	109.2	33.5	13(10)	15(3)	,,	87.2	26.0	17(14)	16(14)
,,	109.5	34.2	19(8)	20(7)	,,	81.0	23.6	18(15)	15(0)

each inner base of the fifth pereiopods have been overlooked by previous investigators, likewise the luminous organs.

The specimens on hand tally well with the descriptions and illustrations of BATE, WOOD-MASON, ALCOCK and DE MAN, except for BATE'S figures (1888, Pl. 44, fig. 4 and Pl. 49, fig. 2), in which the rostrum is shown more strongly elevated, the rearmost rostral spine more backwards (at about one-fifth of the carapace) and the distance between the bases of the last pereiopods of female much narrower.

Genus *Aristaeomorpha* WOOD-MASON

Aristaeomorpha, WOOD-MASON, 1891, p. 286.

Aristeomorpha, ALCOCK, 1901, pp. 13 and 38; BOUVIER, 1908, pp. 15, 52-53.

Aritaeomorpha foliacea RISSO

(Figs. 1, *A*; 8, *Z*; 14, *E*; 19, *B*; 23, *C* and *D*; 36, *E* and *F*; 44, *A*-*C*; 65, *C* and *D*; 72, *A* and *G*; 78, *F*; 87-89).

Aristeomorpha foliacea, BOUVIER, 1908, pp. 53 56, pl. 3, fig. 1 and pl. 11, figs. 1-5.

Aristaeomorpha foliacea, KEMP and SEWELL, 1912, pp. 18 and 19, pl. 1, fig. 5; SCHMITT, 1926, pp. 313, 316 and 317, pl. 57, figs. 1-3.

Aristaeomorpha rostridentata, PARISI, 1919, pp. 59 and 60, figs. 1 and 2.

Aristeus japonicus, YOKOYA, 1933, p. 3, fig. 1.

Rostrum well developed, proximally horizontal, but inclined upwards in distal half at an angle of ca. 20°, about 0.9 times as long as carapace, proximally rather deep but gradually gets shallower toward tip and almost styliform in distal half, bearing well defined straight lateral carina in proximal half; upper border proximally somewhat crested with convex margin, armed from posterior portion of the crest to tip with 9 equidistant spines, posterior 5 or 6 of which are larger than the rest, and the posterior two always located on carapace, the hindmost one inserted at about one-sixth of carapace; lower boarder unarmed. Carapace belongs to Type-A_{1d}; armed with antennal, pterygostomian and hepatic spines which are subequal in size; post-rostral and branchio-cardiac carinae rather marked, post-rostral extends backwards to about the middle of carapace; orbito-antennal, cervical and branchio-cardiac grooves hardly recognizable, but hepatic and inferior ones more developed; marginal region ill-calcified, with antero-lateral border bluntly bending at right angles. Abdomen dorsally carinated posterior to third segment, posteriorly ending in a sharp spinule in each; sixth somite furnished on either lateral surface with rather defined three cicatrices. All pleonic sternites carry a median process, and first three have strikingly developed one. Telson tapering into a sharply pointed tip, about four times as long as wide measured at the broadest region, not reaching to tip of inner uropod, provided with a shallow dorsal median groove as well as a well defined dorso-lateral carine on either side, and four pairs of movable lateral spines, the first of which is situated at ca. five-ninths. Antennular peduncle segmented into three, basal segment armed with stylocerite nearly reaching to proximal margin of second segment and a minute antero-lateral spine which extends to about one-third of second segment; second segment equals to third one in length but about half the length of basal one; outer flagellum inserted near proximal end of dorso-lateral surface of third peduncular segment, less than half the length of peduncle; inner flagellum attached to end of third peduncular segment, greatly longer than body. Antennal scale about twice as long as wide, with straight outer margin ending in a spine, far exceeded by rounded distal margin of lamella. Carpocerite subcylindrical, almost reaching to two-thirds of scaphocerite. Mandibular palp two-segmented, almost attains posterior end of antennal scale; basal segment somewhat widened anteriorly, about 2.6 times as long as wide measured at the broadest region; terminal segment with remarkably concave anterior margin bearing rather long thickly set hairs, about two-thirds the length of basal one (Fig. 8, *Z*). Maxillula is of Type-F_{1a}, endopodite gradually narrowed towards tip, strongly curves forward in distal about half, with rounded apex bearing rather long hairs (Fig. 87, *A*). Maxilla is of Type-G_1; inner four strips well developed, rounded at apex, proximal two subequal in size, 3.5 times as long as as wide, but considerably thinner than third which is about thrice the width; ultimate one gradually becomes broader toward apex, about three times the width of first one (Fig. 87, *B*). First maxilliped belongs to Type-H_{2b}; endopodite five-segmented; proportions in length to the last segment: first segment 3.5, second 1.9, third 1.4, and fourth 2; first segment expanded in proximal three-fourths with straight inner margin; second, third, fourth and fifth ones about 3, 1.6, 2 and 2 times as long as wide respectively; exopodite about seven times as long (without apical appendage) as wide, with rounded anterolateral margin and antero-median one tapering into a small pointed projection measuring ca. 10% of lamellar portion (Fig. 87, *C*). Second maxilliped pediform, seven-jointed; ratios in length to dactylus: merus 2.4, carpus 1, propodus 0.9; merus subrectangular in outline, thrice as long as wide, with nearly straight inner and slightly convex outer margins, lamellar in inner about half; carpus and propodus subequal in size, and both about two-thirds the width of merus; dactylus gradually decreases in size toward rounded apex which bears a stout spinule. Third maxilliped exceeds distal end of antennal scale by about half of dactylus; proportions of length to that of terminal segment 3.4 in ischium, 1.5 in merus, 2 in carpus and 1.7 in propodus; ischium has a small but stout spine close to distal ventral margin.

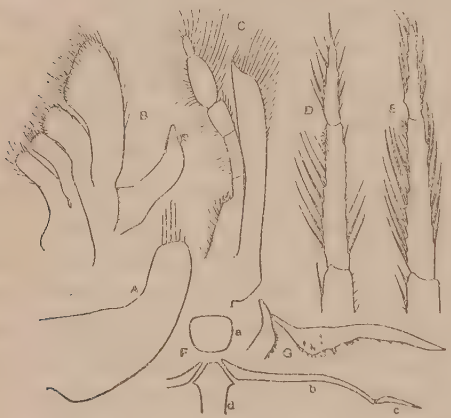

Fig. 87. *Aristaeomorpha foliacea* (Risso). *A*, maxillulary palp; *B*, maxilla without exopodite; *C*, endopodite and exopodite of first maxilliped; *D*, distal segments of third maxilliped (male); *E*, the same as in *D* (female); *F*, cardiac plate (*a*), pterocardiac (*b*), prezygocardiac (*c*), and anterior portion of urocardiac (*d*), ossicles; *G*, distal portion of pterocardiac ossicle and zygocardiac one.

Four pairs of appendages from third maxilliped to third pereiopod fringed with rather long hairs set along anterior and posterior margins. First pereiopod nearly attains tip of stylocerite, decidedly shorter by ca. 25% than third maxilliped; meru, carpus and propodus about 2, 1.5 and 0.6 times the length of dactylus respectively. Second one stretches as forwards as antennal scale, longer (by ca. 30%) and thinner than first one; ratios in length to the last segment: merus 2.5, carpus 2.0, and propodus 0.6. Third one reaching beyond distal end of antennal scale by entire dactylus, longer (by ca. 20%) than second one; proportions in length to dactylus: merus and carpus 2.4, and propodus 0.7. Last two limbs remarkably thin, especially in distal three segments, and much thinner than preceding ones, and attain apex of antennal scale. Fourth one a little (by ca. 7%) shorter than third, with propodus about 0.6 times the length of dactylus. Fifth one longer (by ca. 10%) than fourth one, with propodus about 0.6 times the length of dactylus. Appendix masculina belongs to Type–O_9 (Fig. 65, *C* and *D*). Petasma is of Type–M_2, subtrapezoid in outline; outer margin straight, considerably thickened, about 1.4 times as long as inner margin (Fig. 23, *C* and *D*). Thelycum is of Type–N_1, and consists of a conspicuous almost vertical plate arising from posterior margin of penult thoracic sternite; a process lying on either lateral side of the last thoracic sternite, which is laterally compressed, directed antero-laterally, and touches postero-median surface of fourth pereiopod at base; and there is a prominent median elevation present on posterior edge of the last thoracic sternite (Fig. 44, *A*).

Cardiac plate partly calcified, furnished on inner surface with a longitudinal series of low elevations, first ten of which are well defined and compressed (Fig. 78, *F*). Cardiac ossicle subtrapezoidal with rounded corners, about 0.8 times as long as wide measured at the broadest region (Fig. 87, *F*, *a*). Pterocardiac ossicle is of Type–Q_1 markedly slender, and somewhat tapers toward outer extremity, curves considerably backwards in distal about two-fifths; inner subterminal portion somewhat dilated and gradually becomes narrower toward antero-median end, with postero-median margin lying nearly parallel to antero-lateral rim of urocardiac ossicle. Zygocardiac ossicle has a large sharply pointed conical tooth and a number of tubercles variable in size on inner surface (Fig. 78, *F*). Prezygocardiac elongated, irregularly curved, pointed at both inner and outer ends, armed with numerous sharp setae on inner surface (Fig. 87, *G*). Urocardiac one well defined, with truncate anterior margin, and has a pair of pointed lateral processes directed sidewise near anterior extremity (Figs. 72, *A* and 87, *F*, *d*). Prepyloric belongs to Type–S_1, ogival in dorsal aspect, strongly curved downwards or forward with sharply pointed tip, devoid of accessory armatures altogether. (Fig. 72, *A* and *G*).

The description given above is based on a male, 122.4 mm long (41.0 mm in carapace-length) and a female, 137.5 mm long (40.5 mm in carapace-length). Other 15 males and 14 females, ranging 58.5–146.0 mm in body-length (17.9–51.0 mm in carapace-length) were also examined.

Locality: Kumanonada (350–450 m), off Owase, Mie Pref.; Numazu and Heta, Siduoka Pref.

Distribution: Bay of Biscay and off the coast of Morocco (500–1300 m) (BOUVIER); Near Gabo Island, Australia (200 fathoms) (SCHMITT); Yokohama, Japan (PARISI); Off Owase, Japan (61–353 m) (YOKOYA).

Note: The rostrum is considerably variable, especially in proportion to carapace-length, in degree of curveture, and in number of spines set on the upper border. The proportion ranges from 0.86∼1.28, and changes inversely and linearly in accordance with increase of the carapace-length, irrespective of sex (Fig. 1, *A*). The upward deviation in about distal half from level of the lateral carina is found to vary from ca.

7–20°, mostly 15°–20°. The upper rostral spines are mostly 9 in number, though they range from 8 to 12. As regards 16 specimens having uninjured rostrum, one has 8, eight have 9, four have 10, two have 11, and one has 12 spines.

Proportion in length, measured from anterior margin of carapace to the posterior end of the hepatic groove, to breadth at the widest portion of the pterygostomian region ranges 2.92∼3.70, so far as the present investigation goes (Table 15). It is worthy of mentioning that the proportion becomes greater with increase of the carapace-length (Fig. 88, *A*).

With regards to the sixth abdominal somite, ratio of length to width measured at the broadest region of the lateral surface diminishes linearly during the growth of the prawn as referred to the carapace-length (Fig. 88, *B*). Remarkably enough, the ratio is found smaller than 1.5 in specimens larger than 40 mm in carapace-length (ca. 120 mm long), although SCHMITT (*op. cit.*, p. 316) says "In both *A. rostridentata* and *A. foliacea*, the length of the sixth abdominal somite varies from 1.5 to 1.66 times its greatest depth."

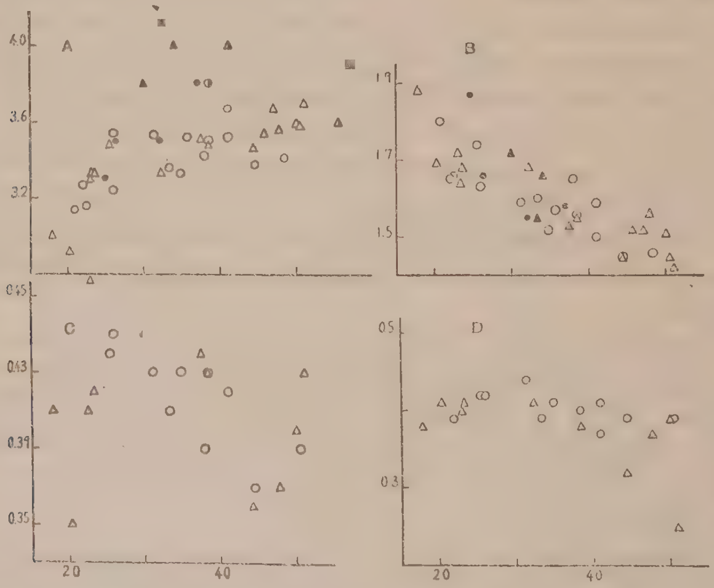

Fig. 88. Ratios of body-parts of *Aristaeomorpha foliacea* in relation to carapace-length (in mm). *A*, ratio of length of pterygostomian region against the largest breadth of the region in question; *B*, ratio of length of sixth pleonic segment against the largest width of lateral surface of the segment; *C*, ratio, in length, of dactylus of fourth pereiopod against propodus of the same leg; *D*, ratio, in length, of dactylus of the last leg against propodus of the same leg. Circles, male; triangles, female. Solid marks from SCHMITT'S data; semisolid marks from KEMPS ones.

Table 15. Giving body-length (BL); carapace-length (CL); length of pterygostomian region (LP) measured from anterior margin of this region to posterior end of hepatic groove; greatest breadth of the same region (BP); length of propodus (P) and dactylus (D) of fourth and fifth pereiopods; and ratios (LP/BP), and (D/P). Dimension in mm.

No.	Sex	BL	CL	LP	BP	LP/BP	Fourth leg			Fifth leg		
							P	D	D/P	P	D	D/P
1	♀	146.0	51.0	23.0	6.2	3.70	14.0	6.1	0.43	16.0	4.0	0.25
2	"	137.5	47.0	20.2	5.5	3.67	—	—	—	—	—	—
3	"	131.0	45.7	20.2	5.7	3.54	—	—	—	—	—	—
4	♂	127.0	41.0	18.0	5.1	3.52	11.0	4.5	0.40	14.0	5.2	0.37
5	"	105.0	34.9	15.0	4.5	3.33	10.4	4.5	0.43	12.0	5.0	0.41
6	♀	130.0	44.3	19.4	5.6	3.46	14.0	5.1	0.36	15.8	5.2	0.32
7	"	141.0	50.5	21.5	6.0	3.58	12.0	4.7	0.39	10.8	4.3	0.39
8	"	140.0	47.8	21.4	6.0	3.56	15.0	5.6	0.37	16.0	6.0	0.37
9	"	140.5	50.0	21.9	6.1	3.59	15.0	6.1	0.40	16.0	6.3	0.39
10	♂	122.4	41.0	18.0	4.9	3.67	—	—	—	12.0	5.0	0.41
11	"	98.0	31.2	13.8	3.9	3.53	10.0	4.3	0.43	11.2	5.0	0.44
12	"	113.5	38.0	16.8	4.9	3.42	10.8	4.3	0.49	—	—	—
13	"	109.2	33.4	16.8	5.0	3.36	11.0	4.5	0.41	13.0	5.1	0.39
14	♀	101.2	32.2	14.0	4.2	3.33	—	—	—	11.0	4.5	0.41
15	"	113.0	37.5	16.5	4.7	3.51	12.0	5.3	0.44	—	—	—
16	♂	129.0	44.5	19.9	5.9	3.37	14.5	5.5	0.37	13.0	5.1	0.39
17	"	107.5	35.6	15.5	4.4	3.52	—	—	—	—	—	—
18	"	—	38.5	17.5	5.0	3.50	11.0	4.8	0.43	13.0	5.3	0.40
19	"	131.5	48.4	20.5	6.0	3.41	—	—	—	—	—	—
20	♀	114.2	38.5	17.4	5.0	3.48	11.5	5.0	0.43	13.0	5.0	0.38
21	"	74.5	23.5	10.0	3.0	3.33	—	—	—	—	—	—
22	♂	80.0	26.0	11.0	3.1	3.54	8.7	4.0	0.45	10.0	4.2	0.42
23	♀	74.8	23.4	10.0	3.0	3.33	7.6	3.2	0.42	8.5	3.5	0.41
24	"	65.2	20.2	8.2	2.8	2.92	7.0	2.5	0.35	7.0	2.9	0.41
25	♂	83.2	25.5	11.5	3.3	3.48	8.5	3.8	0.44	9.4	4.0	0.42
26	"	—	22.0	9.5	2.9	3.27	7.6	3.2	0.42	8.8	3.5	0.39
27	"	81.0	26.0	11.6	3.1	3.24	—	—	—	—	—	—
28	"	74.0	22.5	9.8	3.1	3.16	8.5	3.6	0.41	—	—	—
29	♀	70.6	23.0	9.9	3.0	3.30	7.6	3.5	0.46	8.6	3.5	0.40
30	♂	69.0	20.7	8.8	2.8	3.14	—	—	—	—	—	—
31	♀	58.5	17.9	7.5	2.5	3.00	6.0	2.5	0.41	6.7	2.6	0.38

Concerning the fourth pereiopod, ratio of length of dactylus to that of propodus displays variation ranging 0.35 to 0.46 with no relation to sex (Table 15). It seems that the ratio changes reversely with growth of carapace in length (Fig. 88, *C*). The same ratio, in the fifth pereiopod, extends from 0.25 to 0.44, but mostly 0.4 in both sexes (Fig. 88, *D*).

The reader is referred to Fig. 89 for the sexual difference of the fourth pereiopod. It is thicker by half and somewhat shorter than the fifth in male but both are subequal in thickness and length in female.

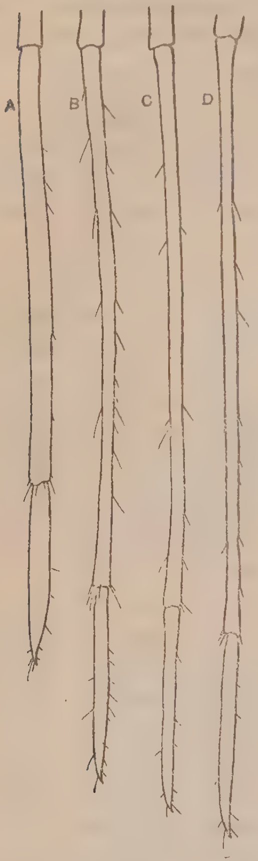

Fig. 89. Showing sexual modification of fourth and fifth pereiopods of *Aristaeomorpha foliacea.* *A*, fourth pereiopod of male, 127 mm long (41 mm in carapace-length); *B*, fourth pereiopod of female, 130 mm long (44.3 mm); *C*, fifth of male, 127 mm long; *D*, fifth of female, 130 mm long. Each figure magnified 6 times.

The present species is very closely related to *Aristacomorpha rostridentata* (BATE) (BATE, 1888, p. 317, pl. 51), and the identification of these two forms is no easy task. But the following items suggested by KEMP and SEWELL (*op. cit.*, p. 18) are valuable standards for recognition of the present species from *A. rostridentata* viz., (1) rostrum longer but less curved upwards, (2) length of pterygostomian region is more than 3.5 times its greatest breadth, instead of being less than 2.5 times as long as broad in *A. rostridentata*, (3) branchial region is much narrower, and (4) dactylus is less than half times the length of propodus in the last two pereiopods. Of these the second was taken the most important by them, and subsequently verified by SCHMITT (*op. cit.*, p. 316) dealing with Australian specimens.

The specimens at the author's disposal tally well in principal characters given above with the descriptions and illustrations of KEMP and SEWELL's and SCHMITT's *A. foliacea.* Such being the case, the specimens are identified as the present species in this paper.

PARISI (*op. cit.*), referred a prawn from Yokohama to *A. rostridentata.* But its pterygostomian region, according to his illustration, intimately resembles that of the present species. Therefore PARISI's *A. rostridentata* may have to be identified as *A. foliacea.*

Aristeus japonicus was erected by YOKOYA (*op. cit.*), basing on two males with aberrant rostrum secured from Kumanonada off Owase, Mie Pref. This species is, however, unquestionably synonimous with the present species, since YOKOYA's description and figures agree well with our specimens and those of BOUVIER (*op. cit.*), KEMP and SEWELL, and SCHMITT in all the important characters.

Subfamily *Solenoerinae* WOOD-MASON and ALCOCK

Solenocerina. WOOD-MASON and ALCOCK, 1891 Solenocerinae, BURKENROAD, 1934, pp. 63–65 Penaeinae, series Haliporae, BOUVIER, 1908, p. 77. Penaeinae (pars), ALCOCK, 1901, pp. 11–12.

The most important for recognition of the present subfamily are that (1) the antennular flagella are rather long (usually somewhat longer than carapace) and flattened or very long (longer than body) and filiform; (2) the cervical groove extends nearly or quite to the dorsum of carapace; and (3) the postorbital or postocular spine is present except *Solenocera maldiviensis* BORRADAILE, in which it is deficient, according to BURKENROAD (1934, p. 65).

Besides these, the following three branchial elements are also striking features of the subfamily, viz., (1) a pleurobranchia lies on the last thoracic somite, (2) a pair of arthrobranchiae is present on the penult thoracic somite, and (3) a mastigobranchia grows on the seventh thoracic one. However, the first is common to the genus *Penaeus* and subfamily Aristaeinae, the second is shared by subfamilies, Aristaeinae and Sicyoninae, and the last by genus *Aristaeomorpha.*

It should be noticed in this place that the annexed trait is peculiar to all the Solenocerinae dealt with, viz., the appendix masculina possesses a calcified projection on outer surface and two scales on distal inner edge.

Three genera, *Hymenopenaeus*, *Haliporus*, and *Solenocera*, have been included within the present subfamily. However, a scrutiny of specimens of *Haliporus sibogae* has induced the present author to find out many characters of it so widely different from those of other species of the genus in question. Hence, the erection of *Parahaliporus* for reception of *H. sibogae.* Four genera are thus recognizable as given below.

Key to the genera of Solenocerinae

A_1 Antennular flagella cylindrical or subcylindrical; post-orbital spine absent; an arthrobranchia supported on seventh body-segment
- B_1 A rudimentary podobranchia absent on third and fourth thoracic somites
  - C_1 Supra-hepatic spine present; petasma without numerous setae along distal margins; ptero-cardiac ossicle simply bar-shaped ....*Parahaliporus.*
  - C_2 Supra-hepatic spine absent; petasma with numerous setae along distal margins; ptero-cardiac ossicle bifurcate at outer end ....*Haliporus.*
- B_2 A rudimentary podobrachia present on third and fourth thoracic somites .... *Hymenopenaeus.*

A_2 Antennular flagalla foliaceous, post-orbital spine present; supra-hepatic spine absent; petasma furnished with numerous setae along distal margins; ptero-cardiac ossicle bifurcate at outer end; two arthrobranchiae lie on seventh body-somite ....*Solenocera.*

Parahaliporus gen. nov.

Shell pubescent. Rostrum well-developed with teeth. Carapace furnished with clear-cut cervical, which extends near mid-dorsal line, and hepatic as well as branchio-cardiac grooves besides illdefined orbito-antennal one, armed with epigastric, antennal, postantennal, pterygostomian, hepatic, and suprahepatic spines; marginal region well-defined, but less calcified. Abdomen dorsally carinated in third to sixth segments, each carine ending in an acute spinule. Telson gradually tapers into a sharply pointed tip, bearing a dorso-median groove and a pair of inmovable spines near extremity, greatly exceeded by tip of inner uropods. Eyes large, reniform, well-pigmented. Prosartema present. Antennular flagella filiform, much longer than body. Antennal scale broad, flagella longer than those of antennules. Mandible furnished with molar and incisor processes which are anteriorly separated by a triangular depression, but posteriorly united with each other; palp two-jointed with very narrow distal segment. Second and third maxillipeds pediform. Petasma foliaceous, longitudinally folned, not fringed with numerous setae along distal margins: cross-section is of Type–PC_1. Thelycum simple. Appendix masculina carries two distal scales and a spur-like protuberance on proximal outer surface.

Cardiac plate on inner surface with a number of equidistant spinules arranged in a longitudinal row. Prepyloric ossicle has many teeth along postero-lateral rim.

Branchial and exopodal formulae equal to those of genus *Hymenopenaeus* as given in Table 6, *D*.

Genotype. *Parahaliporus sibogae* (=*Haliporus sibogae* De Man).

The genus newly proposed herewith is the nearest one to *Hymenopenaeus*. in general respects, but with the salient differences separating one from the other as already given.

Moreover, *Parahaliporus* closely resembles *Haliporoides* (Stebbing, 1914, pp. 20–21), especially in possession of one or two teeth on the lower border of rostrum and trifurcate telson. But it may be distinguished from the latter by having the following characters: mandibular palp two segmented instead of being three-segmented; first pereiopod has a tuft of short setae on each distomedian edge of carpus and proximomedian edge of carpus (in *Haliporoides*, first limb has " clasping arrangement of spines between the distal margin of the fifth joint and proximal of sixth ").

Parahaliporus sibogae (De Man)

(Figs. 1, *O*; 8, *C'*; 9, *A*; 14, *D*; 23, *I* and *J*; 36, *A–D*; 44, *E* and *F*; 66, *Q* and *R*; 68, *O*; 72, *E* and *K*; 81, *D*; 90).

Haliporus sibogae, De Man, 1911, pp. 38–43, pl. 3, figs. 10 and 10a–b, and pl. 4, figs. 10c–q; Schmitt, 1926, pp. 317–318; Yokoya, 1933, p. 3.

Maxillula strongly compressed, consists of inner and outer laciniae, and an exopodite. Inner lacinia the smallest, thumb-like in outline, strongly directed inward, provided with anterior and posterior borders nearly parallel with each other, rounded on distal margin bearing thickly set hairs. Outer endite the largest, projecting slightly antero-medially, gradually increasing in width toward apex, truncate and clad with rather long hairs set as thick as those of inner laciniae on distal edge. Endopodite intermediate in size, pointing obliquely sidewise, unsegmented with rounded apex, successively narrowed toward tip, furnished with several long setae set equidistantly in distal one-third of anterior margin (Fig. 90, *A*). Maxilla is of Type–G_1; endopodite papilla-like, unsegmented, inner margin somewhat concave, fringed with thickly set short setae in distal half; outer margin rather suddenly curved inward at about three-fourths, provided with a thicket of rather short stout setae in subterminal portion (Fig. 90, *B*); exopodite-ear-shaped, with both anterior and posterior margins rounded, the former extends as far forwards as anterior end of distal gnathobasis. First pereiopod stretches as far as tip of antennal peduncle, carpus has a thicket of short setae on distal inner border, and propodus also bears a similar one on proximal inner edge. First pleonic appendage of male has a small well-calcified plate just behind insertion of petasma (Fig. 90, *C*). Petasma belongs to Type–M_2 (Fig. 23, *I* and *J*); dorsal lobule of median lobe about two-sevenths the length of lateral lobe, ventral lobule of the lobe folded longitudinally and gradually tapers forwards into a large bluntly pointed projection which is as long as median lobule; lateral lobe subtriangular in outline, about twice as long as wide measured in the broadest region, gradually narrow anteriorly to a prominent projection which is with truncated distal edge running postero-laterally and considerably wider and slightly longer than that of median lobe, basal outer portion rather broadly auriculete with rounded margin; a round-topped protuberance directed sidewise, lies near base of anterior surface.

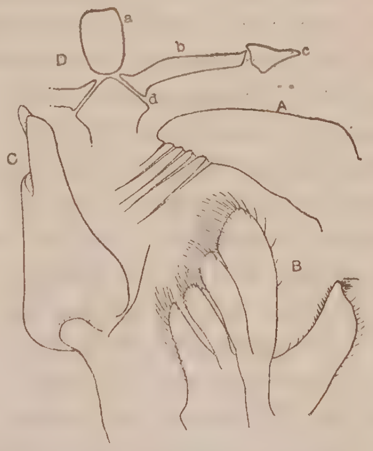

Fig. 90. *Parahaliporus sibogae*. *A*, endopodite of maxillula, ×20; *B*, maxilla without exopodite, ×10.5; *C*, petasmal endopodite (posterior view) of a young male, 97 mm long (24.5 mm in carapace-length), ×7.5; *D*, cardiac (a), pterocardiac (b), prezygocardiac (c), and anterior part of urocardiac (d), ossicles, ×10.5.

Appendix masculina is of Type–O_{10} (Fig. 66, *Q* and *R*); proximal piece carries on outer surface a large well-calcified pointed process directed downwards; distal piece made up of anterior and posterior scales, each of which bill-like with rounded apex, but anterior scale overlaps a greater part of the other.

Epipodite lying on each thoracic appendage from third maxilliped to fourth pereiopod has a protuberance on posterior border near base, but no podobranchia. The protuberance in question convex on distal border, and furnished with many rather long hairs at apex.

Cardiac plate possesses on inner surface about 17 equidistant pointed spinules arranged in a longitudinal row (Fig. 81, *D*). Cardiac ossicle subrectangular in outline, with slightly emarginate anterior and convex posterior margins, about one and half times as long as wide (Fig. 90, *D*, *a*). Pterocardiac bar-shaped, about six times as long as wide, runs at first slightly antero-laterally and curves sidewise at about a third; inner margin straight, lying parallel to antero-lateral edge of urocardiac ossicle; each of inner anterior and posterior angles produced into a bluntly pointed protuberance pointing antero-medially and postero-laterally respectively; outer anterior angle acuminate, directed antero-laterally (Fig. 90, *D*, *b*). Prezygocardiac deltoid, with somewhat curved sides (Fig. 90, *D*, *c*). Zygocardiac armed on inner anterior margin with two large conical teeth, upper one of which is followed by 2–4 accessory teeth set in a longitudinal series. Lateral wall of pyloric chamber, just posterior to zygocardiac ossicle, carries many sharply pointed spinules. Urocardiac much broader than cardiac; terminal portion expanded in the form of a square with bluntly pointed anterior end, and sharply pointed lateral angles (Fig. 90, *D*, *d*). Prepyloric ossicle well-calcified, elongated pentagonal in dorsal view; posterior half decreasing in width and ending in a large median tooth, and furnished on each postero-lateral ridge with about ten acuminate teeth which gradually increase in size and length toward tip of the ossicle (Fig. 72, *E* and *K*).

I have examined 25 males and 29 females ranging 69.5 to 141.1 mm long (17–40 mm in carapace-length).

Habitat: Off Heta and Maisaka (Sizuoka Pref.) and Kumanonada, off Owase (Mie Pref.), 200–400 mm in depth.

Distribution: Flores Sea (521 m); Strait of Makassar (450 m); Banda Sea (462 m); near Kei Islands (397 m) (De Man). Near Gabo Island, New South Wales, Australia (150–250 fathoms) (Schmitt); from Heta to Kagosima Bay, Japan (100–379 m) (Yokoya).

Note: The proportion of the rostral length to the carapace-length shows a variation ranging from 0.41 to 0.57, and the general trend of the changes in the proportion goes down with increase of the age (Fig. 1, *O*). The number of both the upper and lower rostral spines also varies within a limit, namely, 6 to 9, mostly 7 (46.3%) or 8 (39.0%) in the former, whilst from 1 to 3, mostly 2 (85%) in the latter (Table 16, *A–C*). However no correlation is found to exist between the number of these spines and rostral as well as carapacial lengths at least in the specimens at my disposal. The correlation coefficients are −0.296± 0.96 for the number of upper rostral spines and the rostral length, −0.317±0.094 for the number of the same spines and the carapacial length, 0.110±0.104 for the number of the lower rostral ones and the length of rostrum, and 0.074±0.104 for that of the same ones and the carapace-length. It is worth mentioning that there is no sexual difference to exist in the proportional and meristic traits in these material.

Table 16. Correlation tables of rostral spines to rostral length (*A* and *C*) and Carapace-length (*B* and *D*). U. R. S., number of upper rostral spines; L. R. S., number of lower rostral spines; R. L. and C. L., rostral length and carapace-length respectively (in mm); F, frequency.

(A)		U. R. S.				F
		6	7	8	9	
R. L.	8-10	1	5	6		12
	10-12	1	12	10	2	25
	12-14	1	2			3
	14-16					0
	16-18	1				1
F		4	19	16	2	41
%		9.7	46.3	39.0	8.4	

(B)		U. R. S.				F
		6	7	8	9	
C. L.	17-22	1	12	10	1	24
	22-27	1	6	6	1	14
	27-32	1	1			2
	32-37					0
	37-42	1				1
F		4	19	16	2	41

(C)		L. R. S.			F
		1	2	3	
R. L.	8-10	2	9	1	12
	10-12		22	3	25
	12-14		3		3
	14-16				0
	16-18		1		1
F		2	35	4	41
%		4.8	85.3	9.7	

(D)		L. R. S.			F
		1	2	3	
C. L.	17-22	2	20	2	24
	22-27		12	2	14
	27-32		2		2
	32-37				0
	37-42		1		1
F		2	35	4	41

Regarding the mandibular palp, De Man's description and illustration (1911, p. 41, pl. 4, fig. 10, *l*) are contradictory with each other. The palp is delineated as three-jointed with the first articulation (which is represented by weaker line than that of the second) near proximal end of the apparatus. But he describes as follows:—" The hairy mandibular palpi reach, both in the male and in the female, to the base of the antennal scales; the 1st or proximal joint is $2^{1}/_{2}$–times as long as broad, it shows its greatest width at the posterior third and gradually narrows forward, but more rapidly backward and the lower or outer surface is slightly concave; the likewise tapering, 2nd joint is little more than half as long as the preceding and much narrower." In my specimens, the basal segment has ventrally a rather broad ill-calcified cross band in the portion corresponding to the proximal transverse line of DE MAN's illustration, but dorsally a well-calcified triangular swelling with its apex forward instead of such band. Thus the present writer is inclined to consider that the cross band is probably not a real articulation.

The specimens laid down before the writer agree well with the description and figures given by DE MAN (*op. cit.*) except that the upper rostral spines are mostly 7 or 8 and the lower ones usually 2 in number in the present specimens instead of being, as in DE MAN's description, usually 6 and 1 respectively.

Again it should be noticed that the thumb-like small projection found on the peduncle of the first pleopod just behind the insertion of the petasma is represented as boot-shaped by DE MAN (*op. cit.*, pl. 4, fig. 10, *i*).

Genus *Hymenopenaeus* SMITH

Hymenopenaeus, SMITH, 1882, p. 91; 1884, p. 413; BURKENROAD, 1936, pp. 102-106.
Haliporus, FAXON, 1895 (part), p. 189; ALCOCK, 1901, p. 22; BOUVIER, 1908 (part), pp. 78-79; DE MAN, 1911, pp. 31-32; BALSS, 1925, p. 225.
Penaeopsis, FAXON, 1895, p. 185.
Haliporoides, STEBBING, 1914, pp. 20-21.

To the characteristics which have been enumerated as generic traits of this genus the following may be added: petasma serrated with numerous spinules along distal margins; appendix masculina has a spur-like process on proximal piece, in addition to two distal scales; pterocardiac ossicle bifurcate at outer extremity; and prepyloric one armed with a number of markedly small teeth along distal margins.

ALCOCK (*op. cit.*) did not put the branchiae of the first thoracic somite on the formula given by him. The rudimentary arthrobranchiae lying on the first thoracic somite are overlooked by BOUVIER (*op. cit.*, p. 79), as pointed out already by DE MAN (*op. cit.*, pp. 42–43) examining the organs of *Parahaliporus sibogae* (=*Haliporus sibogae*). The branchiae in question are found in our specimens which are referable to two species, *Hymenopenaeus lucasii* and *H. aequalis*.

The genus *Hymenopenaeus* so closely resembles the genus *Haliporus* (BATE, 1881, p. 185, and 1888, p. 284) as these two genera were regarded congeneric by FAXON (1895, p. 191), ALCOCK (1901, p. 22), BOUVIER (1908, pp. 78–79), and BALSS (1925, p. 225). But *Hymenopenaeus* is easily recognizable from *Haliporus* by the absence of podoranchiae on the thoracic appendages posterior to second maxilliped. In the specimens at the auther's disposel, which are referable to *Hymenopenaeus aequalis* (BATE) and *H. lucasii* (BATE), the epipodites attached to thoracic appendages behind the second maxilliped are not furnished with podobranchiae, but suddenly expanded near insertion and provided with rather thickly set hairs on the swollen posterior border, and then graually narrowed distally.

Key to the species of this genus

A. Rostrum horizontally straight, armed on upper border with 6-7 teeth, of which posterior 4 always situated on carapace; lower antennular flagellum thicker than upper one, somewhat compressed, furnished with thickly set hairs along dorsal and ventral borders; petasma of adult form carries a prominent bluntly pointed projection on each anteromedian angle of median lobe, numerous fine setae set on distal margins quite inconspicuous, process *a* scaly; projection placed on proximal piece of appendix masculina rounded at apex ……… *H. lucasii* (BATE).

B. Rostrum straight, inclined upwards at an angle of ca. 20°, provided on upper border with 7 teeth referable to anterior and 2 posterior teeth, the latter lying somewhat posterior to gastric region; lower antennular flagellum cylindrical, devoid of hairs; petasma not provided with pointed projection at each anteromedian angle, distal margin furnished with numerous fine setae, process-*a* hardly recognizable; projection found on proximal piece of appendix masculina sharply pointed at apex *H. aequalis* (BATE).

Hymenopenaeus lucasii (BATE)

(Figs. 8, *B′*; 20, *Q*; 27, *K-N*; 66, *O* and *P*; 72, *C* and *I*; 80, *H*; 91; 92, *A-C*)
Haliporus lucasii, BOUVIER, 1908, p. 80.
Solenocera lucasii, BATE, 1881, p. 185.
Phylonicus lucasii, BATE, 1888, pp. 277-278, pl. 42, fig. 4.
Pleoticus lucasii, BATE, 1888, p. LXII.
? Haliporus lucasii, DE MAN, 1911, pp. 43-45.
Not: *Solenocera lucasii*, MIERS, 1884, p. 15.
Not: *Solenocera lucasii*, RATHBUN, 1906 (for 1903), pp. 904-905, pl. 20, fig. 9.

Body glabrous except gastric and frontal regions which are more or less tomentous. Rostrum almost horizontal, straight on upper border, sharply pointed at apex, armed above with 7 subequidistant teeth, posterior 4 of them are on carapace and the hindmost one stands at about two-fifths of carapace; lower border unarmed, and gently curving upwards in distal half; each lateral surface furnished with a shallow groove decreasing in width toward tip and defined by upper and lower carinae, of which the upper one is almost horizontally straight and fades away somewhat behind tip of rostrum, the other somewhat tilted upward anteriorly but posteriorly continuous to orbital margin of carapace. Carapace well-calcified exclusive of marginal region. Cervical and hepatic grooves deeply cut, the former slopes up near mid-dorsal line at about three-fifths of carapace, the latter extends below upper end of cervical groove. Orbito-antennal groove rather defined. Postrostral and pterygostomian carinae present, the former running above upper ends of cervical grooves. Antennal, postantennal, branchiostegal and hepatic spines present, all of which subequal in size; antennal one laid down at infra-orbital angle, postennal a little posterior to antennal one, branchiostegal close behind anterolateral margin of carapace. Abdomen sharply carinated along mid-dorsal line posterior to second pleonic somite, each carina of third to fifth somites deeply incised at posterior end for reception of dorsal carina of next somite, but the carina of sixth somite terminates in an acute spinule directed rearwards. Pleuron of first abdominal somite has a short ill-defined narrow depression passing upward from about middle of inferior margin. Sixth pleonic somite a little less than half the length of carapace, about 1.4 times as long as wide, without cicatrices on each lateral wall. Telson gradually tapers into an acuminate tip, as long as sixth pleonic somite, not reaching to tip of inner uropod, provided with a shallow dorsal median groove which disappears at about two-thirds where a pair of inmovable acute spine present. Eyes rather small, ca. 3 mm in longer diameter, well-pigmented. Antennule well-developed; basal segment bears prosaltema which reaches well beyond eyes, an acute stylocerite attaining almost apex of eyes, and a sharply pointed spine which extends to about middle of second peduncular joint at antero-lateral angle; second joint subcylindrical, about a quarter as long as carapace; third one a little less than half the length of second one. Upper antennular flagallum about 1.9 (in male) or 1.4 (in female) times the length of carapace, with ventral hairs in proximal about one quarter which is considerably thickened but remaining three quarters successively decrease in size toward tip. Lower antennular one rather compressed, oval in cross-section (ratio of shorter diameter to the longer one is ca. 0.74), about 1.6 and 1.3 times the length of carapace in male and female respectively, much thicker and somewhat longer than upper antennular flagellum, fringed with rather thickly set long hairs along both upper and lower borders. Basicerite has a stout spine directed forwards on antero-lateral margin. Scaphocerite rather narrow, about 3 times as long as wide measured in the broadest region, gradually tapers toward rounded apex, extends beyond tip of antennular peduncle by its one-sixth, straight on outer margin and has an acute disto-lateral spine which projects forward far beyond distal rim of lamella. Carpocerite cylindrical, reaching to about middle of scaphocerite. Mandible has both molar and incissor processes defined by a triangular depression lying between them. Molar process somewhat indented on masticatory surface; inner masticatory edge sharper and higher than the other, having a notch near anterior end and a pointed tooth at posterior end. Incisor one carries two acuminate teeth on cutting rim, one at anterior end and the other at about middle. Mandibular palp falls a little short of tip of scaphocerite; basal segment twice as long as wide measured in the widest region, inner edge slightly convex except deeply excavated proximal quarter, but outer one simply convex; the last joint narrow, gradually tapers into a bluntly pointed tip, ca. 3 times as long as wide (Fig. 8, B'). Maxillula and maxilla are of Type-F_{1a} and -G_1 respectively, closely resemble those of *Paraharipolus sibogae*. First maxilliped is of Type-H_{2a}; inner distal lacinia rather broad with rounded apex, ca. 2.2 times as long as wide; endopodite 5-segmented, successively diminishing in size toward tip, ratios in length to the last segment: first 2, second 0.7, third 0.6 and fourth 1.3, penult segment about one-sixth as wide as long; exopodite narrow with pointed apex, ca. 8.5 times as long as wide, surmounting tip of inner distal lacinia by its one-third. Second maxilliped 7-segmented, basal three joints subequal in size, each of which about half the length of the last segment. merus subrectangular in outline with parallel sides, ca. 3.5 times as long as wide, rather lamellar on inner side; distal 3 joints also subequal in length, but penult one the stoutest and antepenult a little stouter than the last one which ends into rounded apex. Third maxilliped reaches beyond tip of antennal scale by half of dactylus, proportions in length to the last joint: ischium and carpus 1.6, merus and propodus 1.3; merus ca. 4 times as long as wide, and as wide as carpus; dactylus bluntly pointed at apex, ca. 6 times as long as wide.

First pereiopod nearly extends to tip of mandibular palp, shortest of all legs, ca. 70% in length of third maxilliped (Fig. 91, *A*); proportions in length to movable finger (2 mm): ischium 1.3, merus 2.1, carpus 2.0, palm 0.6; each segment except fingers subequal in width, both basis and ischium of each have a spine at distal lower angle; merus ca. 4 times as long as wide, armed with a spine at midway of inferior rim; each finger of chela straight on cutting edge, pointed at tip. Second one longer and slenderer than the first, reaching a little beyond middle of scaphocerite, proportions in length to dactylus (2.1 mm): ischium 1.3, merus 2.5, carpus 3.1, palm 0.7; each joint exclusive of dactylus subequal in size; ischium has a spine at disto-ventral angle; carpus about 10 times as long as wide; fingers straight on prehensile edges, pointed at tip. Third one longer (by ca. 20%) and slenderer than the second, streches to apex of scaphocerite, devoid of spinous armatures, ratios in length to movable finger (2.1 mm): ischium 1.4, merus 3.2, carpus 5, palm 0.9; ischium and merus subequal in breadth, the latter ca. 8.3 times as long as wide; distal 3 joints somewhat thinner than merus, carpus and palm ca. 18.3 and 2.3 times as long as wide respectively; fingers of chela closely resemble those of preceding two chelae. Fourth one reaches to about two-thirds of the scale, subequal to third pereiopod in length (Fig. 91, *A*) but slenderer; ratios in length to dactylus (2 mm): ischinm 1.7, merus 3.3, carpus 4, propodus 1.6; ischium and merus thicker than distal three segments, merus and propodus ca. 10.5 and 8 times as long as wide respectively, dactylus tapers and tipped with many wavy hairs. Fifth one longer than fourth by about 60%, surmounts far end of antennal scale by about half of propodus and entire dactylus, proportions in length against dactylus (2.6 mm): ischium 1.9, merus 5, carpus 5.2, propodus 3.8; merus and propodus ca. 17 and 32 times as long as wide respectively, the last joint similar to that of fourth leg in general aspect.

Petasma belongs to Type-M_5; ventral free margins well calcified and thickened; dorsal lobule of median lobe outstandingly projecting forward with bluntly pointed apex at distomedian angle (Fig. 27, *K–N*, d); each ventral lobule of median lobe and dorsal lobule of lateral lobe form a lateral outbulging (Fig. 27, *K–N*, e); process-*a* inserted somewhat posterior to apex of ventral free margin, scaly, subquardrate in outline, rounded at apex, well-calcified and considerably thickened, destitute of setae, and hardly reaches to apex of lateral lobe (Fig. 27, *K*, *L* and *N*, c): process-*b* situated above process-*a*, well-calcified, bare and rather thin, rounded at apex, directed antero-ventrally (Fig. 27, *K–N*, b).

Appendix masculina is of Type-O_{10} (Fig. 66, *O* and *P*). Proximal piece furnished on outer margin with a large compressed projection which is directed ventro-laterally, markedly dilated in distal portion which terminates with rounded apex. Distal one made up of two inner and outer scales which are rounded at apex, directed downward. Inner scale about 1.7 times the length of the projection lying on outer surface of proximal piece, considerably thickened in basal half, and fringed with hairs on distal margin and in proximal half of posterior one. Outer scale about 0.6 times the length of inner one.

Cardiac plate armed with 6 spinules alined longitudinally on inner surface (Fig. 80, *H*). Cardiac ossicle subrectangular in outline, somewhat longer than wide, a little emarginate on anterior and both lateral margins, and more or less convex on posterior borders (Fig. 92, *C*, *a*). Pterocardiac bar-shaped, gradually widened toward outer extremity, bifurcate at outer end for reception of prezygocardiac ossicle, about 12 times as long as wide measured at middle, and ca. 1.2 times the length of cardiac ossicle (Fig. 92, *C*, b). Prezygocardiac minute, bar-shaped, with sinuous anterior and posterior borders, rounded at tip, about half the length of pterocardiac one. Urocardiac somewhat concave on anterior edge, furnished with a large bluntly pointed process on each lateral margin near anterior end. Zygocardiac has two sharply pointed rather large teeth on anterior border. Upper tooth followed by about ten smaller acute teeth which are arranged longitudinally and gradually diminish in size posteriorly (Fig. 80, *H*). Prepyloric strongly curves postero-ventrally in distal half, pointed at tip, armed with about 7 rather vestigial conical teeth along proximal half of postero-lateral borders (Fig. 72, *C* and *I*).

Above mentioned description is based on a male, 72.5 mm long (18.5 mm in carapace-length). Additional specimens including 5 males and 8 females measuring 36.0-76.0 mm long (9.5-20.0 mm in carapace-length) were also examined.

Locality: Kumanonada (200-450 m), off Owase, Mie Pref.

Distribution: Off Ki Islands, south of Papua (140 fathoms) (BATE).

Note: The rostral teeth are mostly 7 in number, viz., of 14 specimens, 13 have 7 teeth and 1 has 6. But the posterior 4 teeth of them are found on the carapace without exception.

Remarkably enough, two females, 18.7 mm and 20.0 mm in carapace-length, are found noticeably deviating from others in relative size of cornea as referred to the length of carapace (Fig. 91, *C*). But it appears to the writer, so far as the present material goes, to be merely fluctuations within one species.

The antennular flagella exhibit a secondary sexual difference: the flagella of male are longer than those of females (Fig. 91, *B*).

Relative lengths of the third maxilliped and all the pereiopods against carapace-length are linear in trend (Fig. 91, *A*-*B*). Proportions in length to carapace-length are about 1.35 in the third maxilliped, 1.25 in the second cheliped, 1.6 in both third and fourth pereiopods, and 2.5 in the last one.

The appendix masculina of a young, 36 mm long (9.5 mm in carapace-length) is found essentially well differentiated already. But it differs from adult form in having distal inner and outer scales relatively longer, ca. 2.3 and 2 times the length of the projection lying on outer surface of proximal piece respectively; posterior margin of distal inner scale more deeply notched at about one-third.

The petasma of the same juvenile specimen also remarkably differs from that of the adult as follows:—the disto-median projection of the median lobe is not yet well developed, and the distal free margins finely fimbriated with numerous setae (which are absent in adult).

The specimens dealt with herein agree well with BATE'S description and figures of the present species. However, he evidently overlooked (BATE *op. cit.*, p. 279) the meral spine of the first and basial one of the second pereiopods, and his illustration (pl. 42, fig. 4) does not show the propodus of fifth pereiopods as already discussed by DE MAN (*op. cit.* p. 44).

The present specimens also tally well with DE MAN'S (*loc. cit.*) minute description exclusive of the following point which is very important for distinction of the present species from others. DE MAN states "The lower antennular flagellum that alone is present,......; this flagellum is cylindrical, not at all compressed,......" But that of our specimens, as given in the descriptive part, is found considerably compressed and fringed with rather long hairs along upper and lower borders from base to subterminal portion. Thus there remains some doubt for identification the specimens with those of ME MAN'S *Haliporus lucasii.*

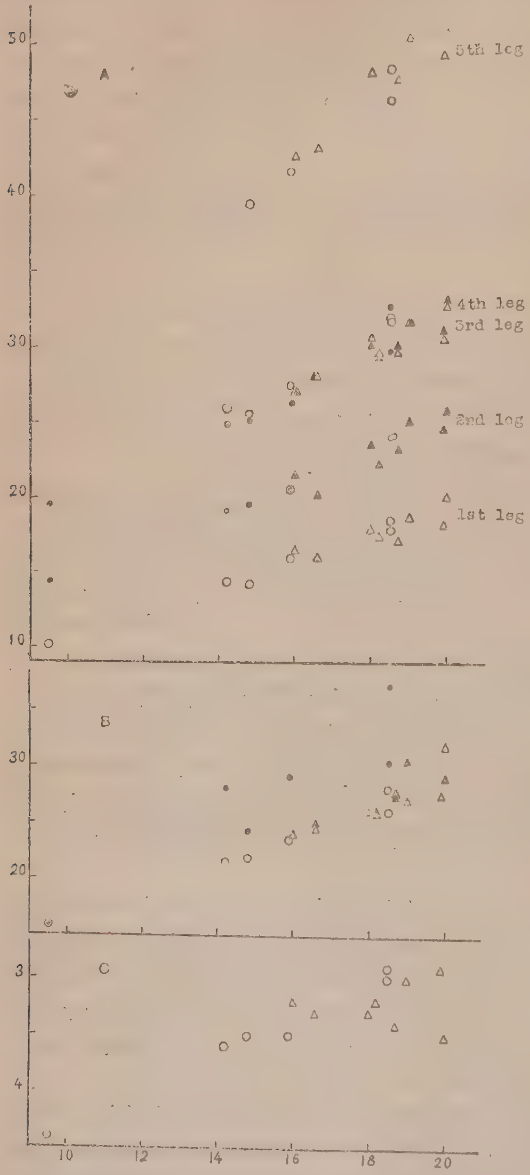

Fig. 91. Dimensions (in mm) in relation to carapace-length of *Hymenopenaeus lucasii.* *A*, pereiopods (soft marks: first, third and fifth legs; solid ones: second and third legs); *B*, upper antennular flagellum (solid marks) and third maxilliped (soft marks); *C*, diameter of cornea. Circles, male; triangles, female.

DE MAN (*op. cit.* pp. 44–45) says "*Halip. malhaensis* BORR. only known by one female dredged in 145 fathoms off Saya de Malha, is apparantly closely related to *Halip. Lucasii* (Sp. BATE) and I should have identified both species, but neither the 4th nor 5th legs are particularly slender in the species from Saya de Malha, while in *Halip. Lucasii* the legs of the 5th pair are very slender, elongate and filiform. I may call, however, the attention to the fact that, in the figure of *Halip. malhaensis*, the propodi of the 4th and of the 5th legs are evidently not figured. (L. A. BORRADAILE, in: Trans. Linnean Soc. London, 2nd Ser. Zool. vol. XIII, 1910, p. 258, pl. 16, fig. 2)". But the specimens at hand are not referable to *Haliporus malhaensis* BORRADAILE, because, according to BORRADAILE'S description and illustration, the latter has posterior three rostral spines lying on the carapace, the upper antennular flagellum not longer than the other, the lower one not provided with rather long hairs along both dorsal and ventral borders, and the antennal scale does not surmount tip of the antennular peduncle.

Both *Solenocera lucasii ?* of MIERS (*op. cit.*) and *Solenocera lucasii* of RATHBUN (*op. cit.*), basing on their descriptions, are not characterized by pterygostomian spine. Thus the present specimens are easily separable from either of them.

Hymenopenaeus aequalis (BATE)

(Figs. 8, *A'*; 20, *R*; 27, *O* and *P*; 66, *M* and *N*; 71, *H*; 72, *D* and *J*; 80, *I*; 92, *D-I*)

Haliporus aequalis, WOOD-MASON, 1891, p. 277; ALCOCK, 1901, p. 23; BOUVIER, 1908, p. 80; DE MAN, 1911, pp. 7 and 31-33; KEMP, 1912, p. 16; BALSS, 1925, pp. 225-226.

Haliporus equalis, BATE, 1888, pp. 285-286, pl. 41, fig. 1; RATHBUN, 1906, (for 1903), p. 905.

Rostrum straight, sharply pointed at apex, directed obliquely upward at an angle of ca. 20°, about two-fifths the length of carapace, reaching about one-third of second antennular segment, provided with a straight lateral carina somewhat inclined dorsally, armed above with 7 teeth decreasing in size and distance lying between each tooth toward tip; the foremost tooth situated a little behind mid-way between tip and second tooth, the rearmost one slightly behind postorbital margin (Fig. 92, *D*). Carapace about twice as long as deep, broadly rounded, on antero-lateral edge. Cervical, hepatic and branchio-cardiac grooves well-marked, the first of which nearly extends to dorsum at about middle of carapace. Postrostral carina reaches to half-way of carapace. Epigastric spines two in number, inserted at one-fourth and one-third of carapace respectively. Antennal, postantennal, branchiostegal and hepatic spines present, subequal in size. Antennal one stands at infra-orbital angle; postantennal at a seventh of carapace, and posterior to antennal one; branchiostegal somewhat behind anterior rim of carapace and slightly below hepatic groove; and hepatic below anterior epigastric tooth. A very minute median tubercle situated a little in front of posterior edge of carapace. Thoracic sternite between fourth pereiopods provided with a heart-shaped elevation. Abdomen dorsally carinated in last three segments; sixth segment sharply pointed at posterior end of dorsomedian carina, without cicatrices, about 1.8 times as long as wide, slightly less than half of carapace. Telson tapers into acuminate tip, furnished with a shallow rather broad dorsal groove and a pair of inmovable spines on subterminal lateral edges, as long as sixth pleonic somite, considerably surmounted by apex of inner uropods.

Eyes rather large, reniform, well-pigmented, somewhat exceeded by rostrum. Antennular peduncle hirsute; basal segment a little surmounts apex of eye, provided with prosartema, which does not reach to apex of eye, stylocerite ending below about middle of cornea, and a spine directed forwards at distolateral angle; intermediate joint subcylindrical, half times as long as basal one; terminal one shorter (ca. 0.8 times) and smaller than second joint; flagella (distal portion wanting) cylindrical, subequal in size, without thickly set hairs. Basicerite armed with a small spine directed forwards on antero-lateral edge. Scaphocerite rather narrow, reaching a little beyond tip of antennular peduncle, somewhat narrowed anteriorly, thrice as long as wide measured in the broadest region, with straight thickened outer margin which ends in an acute tooth extending as far forward as distal rim of lamella. Carpocerite cylindrical, stretching a little beyond tip of first antennular segment.

Mandible is of Type-E_1, cutting rim of incisor process sharp, and has two pointed teeth. Palp attains about two-thirds of carpocerite; basal segment subrhombic, twice as long as wide; distal one more or

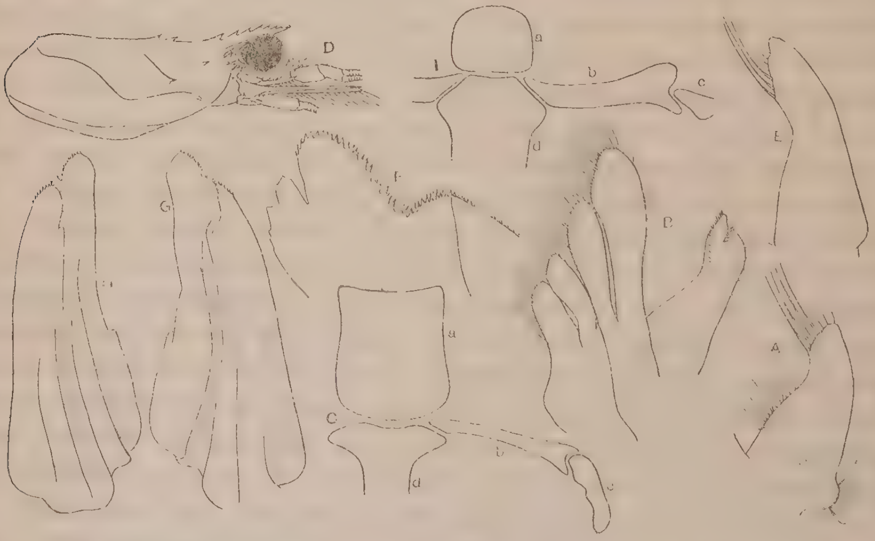

Fig. 92. *Hymenopenaeus lucasii* (*A–C*) and *Hymenopenaeus aequalis* (*D–I*). *A* and *E*, endopodite of maxillula, ×20 in *A* and ×25 in *E*; *B*, maxilla without exopodite, ×15; *C* and *I*, cardiac (*a*), pterocardiac (*b*), prezygocardiac (*c*) ossicles and anterior part of urocardiac (*d*) ossicle, ×15 in *C* and ×25 in *I*; *D*, carapace with rostrum and others of a male, 14.5 mm in carapace-length, ×2; *F*, distal margin of a petasmal endopodite of the male, ×35; *G*, and *H*, dorsal (*G*) and ventral (*H*) aspects of a petasmal endopodite of a male, 11 mm in carapace-length, ×20.

less narrowed anteriorly, bluntly pointed at tip, 2.5 times as long as wide measured in the broadest region (Fig. 8, *A′*). Maxillula (Fig. 92, *E*), maxilla and first maxilliped are of Types F_{1a}, G_1 and H_{2a} respectively as in *H. lucasii*. Second maxilliped closely resembles that of *H. lucasii;* proportion in length to dactylus: merus 3, carpus and propodus 1; basal 3 joints subequal in size, shorter than wide, about half the length of dactylus; merus subrectangular in outline, somewhat lamellar on inner side, 3.6 times as long as wide; carpus directed inwards and distally inflated; propodus as long as wide, thicker than carpus; dactylus rounded at apex, twice as long as wide, and as broad as carpus. Third maxilliped reaches beyond tip of antennal scale by half of dactylus, proportions in length to the last article: ischium and carpus 1.7, merus and propodus 1.3; carpus ca. 7 times as long as wide.

Second pereiopod attains far end of intermediate segment of antennular peduncle, slightly thinner than third maxilliped, subequal in size in all other joints than fingers, ratios in length to dactylus: ischium 1.5, merus 3.2, carpus 4, palm 0.7; merus and carpus ca. 14 and 15 times as long as wide respectively; fingers of chela straight on cutting edge, pointed at apex.

Appendix masculina is of Type-O_{10}. Proximal piece has a straight styliform projection directed ventro-laterally on outer surface, and a rather prominent pyramidal elevation on anterior surface near proximal edge. Distal piece consists of two scales, which are concavo-convex, rounded at apex with rather long hairs, subequal in length (Fig. 66, *M* and *N*).

Petasma belongs to Type M_5; dorsal lobule of median lobe two-fifths the length of the other, ventral lobule of median lobe has a bifid strip on inner subterminal rim and many fine setae on distal margin. Dorsal lobule of lateral lobe has also many fine setae along distal border; ventral lobule of the same lobe becomes lanceolate in distal one quarter and finely serrated with many setae in distal about 10% of ventral free margin (Fig. 27, *O* and *P*, *c*). Process-*a* quite vestigial, stands at two-thirds of ventral free margin (Fig. 27, *O* and *P*, *a*). Process-*b* minute, devoid of setae, placed on dorsal surface somewhat anterior to process-*a* (Fig. 27, *P*, *b*).

Cardiac plate with 9–10 teeth alined longitudinally from middle to anterior end (Fig. 80, *I*). Cardiac ossicle subrectangular, somewhat wider than long, rounded on anterior margin (Fig. 92, *I*, *a*). Pterocardiac bar-shaped, ca. 6 times as long as wide measured at middle, dichotomous at outer end with anterior larger and posterior smaller processes with rounded apex, and has a pointed projection directed antero-medially at antero-median angle (Fig. 92, *I*, *b*). Urocardiac rectangular in outline provided with a pair of large pointed processes directed sidewise on lateral edges near anterior end, anterior margin slightly concave, 0.6 times the width measured at middle (Figs. 72, *D* and 92, *I d*). Zygocardiac bears 3 conspicuous sharply pointed teeth along anterior rim, the uppermost of which is followed by about 6 small pointed teeth which are arranged in a longitudinal row and gradually decrease in size posteriorly (Fig. 80, *I*). Prepyloric considerably curves forward or downward in distal half, tapering into a pointed tip, armed with 7 rather rudimentary conical teeth on each postero-lateral edge (Fig. 72, *D* and *J*).

The description given above is based on a male, 14.6 mm in carapace-length. Two males measuring 11.0 mm and 14.5 mm in carapace-length, were also examined. All of them are found mutilated in most part of the antennular and antennal flagella, and larger two of them have the telson broken off in subterminal portion.

Locality: Kumanonada, off Owase, Mie Pref. and Heta, Sizuoka Pref. (200–450 m).

Distribution: Between Philippine Islands and Borneo (250 fathoms) (BATE); Andaman Sea, Arabian Sea, off Ceylon (ALCOCK); near Kei Islands and Bali Sea (538–560 m) (DE MAN); S. W. coast of India (237 fathoms) (KEMP); East coast of Africa (628–1362 m) (BALSS).

Note: The appendix masculina of a young specimen, 39 mm long (11 mm in carapace-length) is as well differentiated as that of adult form.

The petasmal endopodites of the young specimen are not yet hooked together with each other, and differ from those of adult form as follows: ventral lobule of lateral lobe ends in a projection with rounded apex bearing 9 setae in distal half of its ventral border; both process–*a* and subterminal strip still do not make their appearance, but process–*b* is there although rudimentarily (Fig. 92, *H* and *G*).

The three specimens examined agree with BATE'S description and figures. But they are discrepant in the following two items:—(1) in regard to the pleonic somites, BATE put down "Last two somites dorsaly carinated,………", however, all our specimens are found carinated in last three ones as is the case with "Siboga" specimens (DE MAN *op. cit.*, p. 32); and (2) in his illustration (*op. cit.*, pl. 41, fig. 1), the eyes are represented smaller.

DE MAN'S minute description (*op. cit.*) also well conforms with my specimens with only one exception given below. In DE MAN'S specimens, "the rostrum reaches to far end of 2nd antennular article,……… or that reaches to the middle of the terminal joint of the antennular peduncle,………". But it merely extends to about one-third of the second segment of the peduncle in the specimens at my disposal. Such difference, however, seems to be an individual variation within a species.

Genus *Solenocera* H. LUCAS, 1850 (emend)

Solenocera, BOUVIER, 1908, pp. 86-87; DE MAN, 1911, p. 45; BALSS, 1914, p. 5; 1925, p. 226; BURKENROAD, 1936, pp. 120-122; 1939, pp. 6-7.
Philonicus, BATE, 1888, pp. 273-275.
Parasolenocera, WOOD-MASON, and ALCOCK, 1891, p. 276.

Rostrum rather short, armed with teeth above. Cervical and hepatic grooves well defind. Antennal, post-orbital and hepatic spines exist, but branchiostegal and pterygostomian ones present or absent. Abdomen carinated dorsally. Telson has a median groove on dorsal surface, and usually provided with a pair of inmovable teeth on dorso-lateral borders near tip. Eye well pigmented, cornea wider than stalk. Prosartema present. Antennular flagella foliaceous, rather long, longer than carapace; upper flagellum flattish, narrower than lower ramus; lower flagellum concavo-convex, with convex surface outward. Antennal scale rounded on distal border, furnished with a spine at disto-lateral angle. Mandibular palp two-segmented, distal joint triangular in outline, rounded at apex. Maxillulary palp not jointed, roundish on distal edge. Maxilla provided with four stripes on inner side, endopodite unsegmented. First maxilliped carries slender five-jointed palp. Second maxilliped inverted J-shaped, consists of seven articles. Third maxilliped pediform, again made up of seven joints, not sexually dimorphic. Exopodite present on all thoracic appendages.

Petasma bears a pair of spatulate projections on ventral free edges, and has many setae on distal borders. Apendix masculina intricate; proximal piece possesses a spur like outgrowth on inner surface; distal piece composed of two scale-like appendages.

Thelycum simple. A pleurobranchia lies on thoracic somites from third to the last. A pair of arthrobranchiae present on anterior seven thoracic somites. A podobranchia is laid on second maxilliped. A mastigobranchia attached to all maxillipeds and anterior four pereiopods. Cardiac plate with many spinules arranged in a longitudinal series on inner surface. Pterocardiac ossicle dichotomous at outer end. Zygocardiac is of Type-R_4. Prepyloric provided with many pointed teeth along each postero-lateral border.

The characters found on petasma, appendix masculina, and stomodaeal apparatus of the examined species are for the first time given above with a view to supplement demarkation of the present genus.

WOOD-MASON and ALCOCK (1891) erected the genus, *Parasolenocera.* The separation of this genus from *Solenocera* is chiefly based upon the following character; the antennular flagella are "foliaceously expanded, tapering gradually to a very fine setaceous point". But in reality, such filamentous termination of the flagella is often found in *Solenocera* as revealed by the present author. Hence, *Parasolenocera* should be synonymized with *Solenocera*.

With regard to the genus, *Solenocera*, only two species, *Sol. distincta* DE HAAN (1850) and *Sol. koelbeli* DE MAN (1911) have been put on record from our waters. BALSS (1914, pp. 5–6) referred a Japanese prawn to *Sol. distincta*, but his specimen decidedly differs from the species under consideration, because its carapace, according to his brief description, is destitute of pterygostomian spine. Moreover, it is still open to a question whether *Sol. koelbeli* and BALSS' *Sol. distincta* are identical as rendered by BALSS (*loc. cit.*, p. 5) or not: Since their descriptions are too brief to justify their identification. At any rate, two or three species of *Solenocera* may be enumerated as inhabitants of our waters.

It is a great regret to the writer that none of these known species is represented in the material on hand. But the annexed six new forms: *Sol. alticarinata*, *Sol. prominentis*, *Sol. depressa*, *Sol.* pectinulata, and *Sol. subnuda*, may be introduced in this place, besides *Sol. faxoni* DE MAN.

So far as the present investigation goes, the morphological matters of these seven species may be summarized as follows:—

Well developed rostrum with only acute upper teeth is common to all these species.

Ratio of length of the rostrum to that of the carapace, and number of rostral spines changes from species to species within a considerably narrow limit, ranging from 0.19 to 0.31 in the former and from 5–10 in the latter. The ranges of variation of these items overlap one another, so that these traits are less valuable for the taxonomy of these species.

The postrostral carina stretches to posterior margin of carapace in *Sol. prominentis*, *Sol. depressa*, *Sol. subnuda*, and *Sol. alticarinata*. But the carina of the last species deviates greatly from that of other three, as being very high and somewhat lamellar. On the other hand, it does not extend backwards beyond the cervical groove in the annexed three forms: *Sol. faxoni*, *Sol. brevipes* and *Sol. pectinulata*. The anterior foot of the hepatic carina of *Sol. faxoni* and *Sol. pectinulata* rises considerably, especially in the former, in which it shows a lamellar candition and ends in a sharp branchiostegal spine which overhangs anterolateral margin of carapace. Both the cervical and hepatic grooves are found clearly cut throughout all the species dealt with, but the branchiocardiac one is only recognized in *Sol. alticarinata* and *Sol. subnuda*. Presence of ill-defined transverse groove lying at some distance behind the hepatic spine is peculiar to *Sol. faxoni*. A similar shallow groove passing upward from about anterior base of hepatic spine to a portion somewhat postero-lateral to the post-orbital spine is found in five species except *Sol. pectinulata* and *Sol. brevipes.* The minute semicircular pit situated at anterior end of the hepatic groove is present in *Sol. alticarinata, Sol. prominentis* and *Sol. depressa.* The three spines, antennal, post-obital and hepatic, are found to exist without exception, whilst the branchiostegal spine is particular to *Sol. faxoni*, and the pterygostomian one to *Sol. brevipes.*

The telson is armed with a pair of inmovable lateral spines near apex, exclusive of *Sol. subnuda* in which it is unarmed at all.

The eyes are markedly small in *Sol. faxoni*, but in all other species they are moderately large. The antennular flagella are always longer than carapace, and the upper flagelum is always nearly flat and considerably narrower than the other. The mouth-parts are not much variable in configuration. The mandible, maxillula, maxilla, first and third maxillipeds are of the Types, E_2, F_{1b}, G_1, H_{2a}, and I_1 respectively. The incisor process of mandible is unarmed in *Sol. faxoni*, instead of being provided with two pointed teeth in all other species of *Solenocera* dealt with.

The relative growth, as referred to carapace, of each thoracic appendage backward to the second maxilliped appears linear in trend and the trend is similar to all species irrespective of sex, excluding that of the fifth pereiopods of *Sol. brevipes*, in which the relative growth is distinctly smaller than that of any other (Fig. 100). All the thoracic appendages are furnished with exopodites.

The peduncle of the first pleopod carries a calcified tubercle just behind the insertion of petasma, and that of the second one is triangularly elevated on outer surface in male of all the species except *Sol. alticarinata*, in which male is unknown. Appendix masculina is furnished with a spur-like process on outer surface of the proximal piece, and two bill-like scales, of which the distal piece is composed.

The petasma is characterized by possession of numerous marginal setae in distal portion, and of the process–*a* and–*b* as in *Hymenopenaeus.* But the process–*b* is not found in *Sol. brevipes, Sol. subnuda,* and *Sol. depressa.* The thelycum is rather simple.

Branchial arrangement is as follows: throughout all the forms treated herewith, a pleurobranchia is present on each thoracic somite backward to second one; a pair of arthrobranchiae and a mastigobranchia are laid on each of the anterior seven somites, but those of the first somite are vestigial; and a podobranchia is on the second somite only.

The pterocardiac ossicle is bifurcate at outer end. The zygocardiac is armed with 2 or 3 large conial teeth on inner surface, besides 5–12 small pointed teeth arranged in a longitudinal series. The prepyloric is provided with about 10 sharply pointed prominent teeth along each postero-lateral margin.

Key to the species of *Solenocera*

- A_1 Pterygostomian spine absent; telson armed with a pair of immovable spines on subterminal dorso-lateral margins
  - B_1 Inferior margin of hepatic groove, anterior to hepatic spine, not so much markedly raised; post-rostral carina extends to posterior margin of carapace
    - C_1 Postrostral carina posterior to cervical groove, not lamellar
      - D_1 Each lateral lobe of petasma devoid of setae along distal margin, and carries a sharp spine near outer margin in its middle portion of dorsal surface; posterior margin of the last thoracic sternite trapezoidally much elevated with emarginate apical margin: antennular flagella 1.1–1.5 times as long as carapace; antennal scale reachs beyond far end of antennular peduncle ....*Solenocera prominentis*, sp. nov.
      - D_2 Each lateral lobe of petasma bears many short setae along distal margin, and has no spines on dorsal surface; posterior margin of the last thoracic sternite not conspicuous; antennular flagella 1.7–1.9 times the length of carapace; antennal scale not reaching beyond distal end of antennular peduncle ....*Solenocera depressa*, sp. nov.
    - C_2 Post-rostral carina posterior to cervical groove, lammellar ....*Solenocera alticarinata*, sp. nov.
  - B_2 Inferior margin of hepatic groove markedly raised anterior to hepatic spine; post-rostral carina not extending beyond cervical groove
    - E_1 Anterior end of markedly elevated hepatic carina sharply pointed, overlapping pterygostomian margin; eye small; incisor process of mandible without teeth; fifth leg extends distal tip of scaphocerite; setae lying on distal outer margins of petasma less prominent, process-*a* bears no prominent setae along apical margin, and process-*b* armed with 2 or 3 setae on anterior margin; thelycum without any elevations ....*Solenocera faxoni*.
    - E_2 Anterior end of markedly raised hepatic carina blunt, hardly reaches to pterygostomian margin; eye moderate; incisor process of mandible with two teeth; fifth leg streches beyond antennal scale by entire dactylus; setae beset on distal outer margins of petasma prominent, process-*a* armed with a few conspicuous setae on apical margin, process-*b* carries about 12 prominent sharp bristles along inner rim, female unknown ....*Solenocera pectinulata*, sp. nov.
- A_2 Pterygostomian spine present; post-rostral carina not reaching beyond cervical groove; branchiocardiac groove not recognizabl; telson carries a pair of immovable spines, the last limb extends beyond far end of antennal scale by about half of dactylus; ventral lobule of median lobe of petasma distolaterally produced into a pair of strikingly developed elliptical projections with numerous sharp setae along entire margin; the last thoracic sternite of female furnished with a rather prominent tubercle, shorter than wide, situated near center ....*Solenocera brevipes*, sp. nov.
- A_3 Pterygostomian spine absent; post-rostral carina reaches to posterior end of carapace; branchio-cardiac groove rather marked; telson unarmed; fifth pereiopod streches beyond antennular peduncle by distal two segments; either ventral lobule of median lobe of petasma more or less exceeded by somewhat thickened fleshy apical portion of dorsal lobule of the same lobe and carries two well calcified small processes near subterminal lateral margin; thelycum consists of a pair of tubercles attached to posterior rim of penult thoracic sternite, and two different sized conical median processes placed on the last thoracic sternite ....*Solenocera subnuda*, sp. nov.

Solenocera alticarinata sp. nov.

(Figs. 8, *W*; 45, *E*; 72, *P* and *V*; 80, *F*; 93: 94, *A-C*; 100)

Body glabrous except rather narrow tomentous areas of each side of postrostral carina anterior to cervical groove (Fig. 93). Rostrum short, horizontal, sharply pointed, at apex, about one-fifth the length of carapace, reaches nearly middle of first joint of antennular peduncle, with a lateral carina which slopes up to tip arising from postorbital edge; upper border almost straight armed with 9 teeth, posterior 6 are laid down on carapace, the foremost one a little nearer to second tooth than to tip of rostrum, fourth one lies above postorbital margin, last one somewhat vestigial with rather blunt apex lying immediately behind upper end of cervical groove or a little in front of half-way of carapace; lower border considerably convex without teeth. Postrostral carina outstandingly elevated, reaching posterior rim of carapace, but suddenly becomes low in subterminal portion. Supra-orbital spine minute, placed somewhat nearer to rostrum than to infra orbital angle. Antennal one located close behind infra-orbital angle, larger than supraorbital one. Postorbital lying between and backward to supra-orbital and antennal ones, somewhat larger than the latter. Hepatic set below mid-way between sixth and seventh rostral armatures and at inferior one-third of lateral surface of carapace, subequal in size to post orbital one. Cervical and branchio-cardiac grooves clearly cut. Hepatic one also well-marked, gently decurves forward to a minute semicircular pit lying somewhat behind pterygostomian edge, posterior end reaching below upper end of

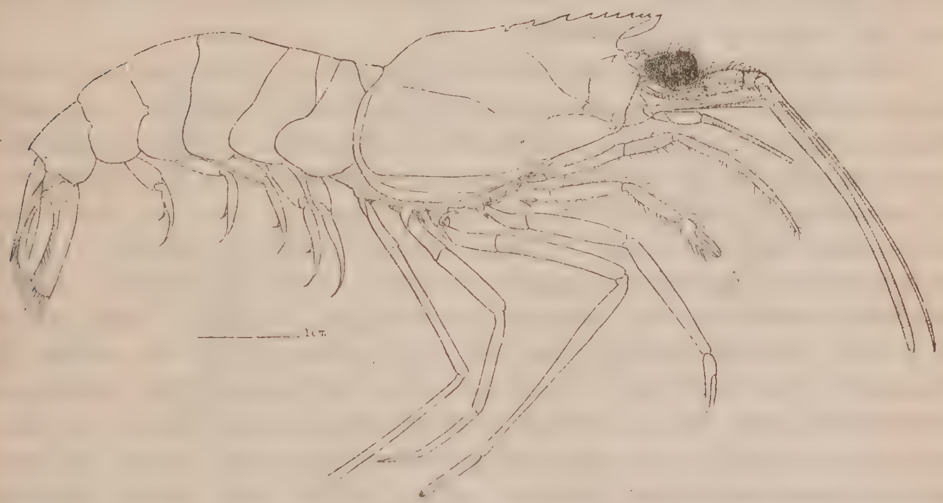

Fig. 93. *Solenocera alticarinata*, sp. nov., female.

cervical groove. Anterior and posterior rather defined, transverse grooves present besides ordinary ones. Anterior one located near posterior port of antennal region, slightly tilted forward, posterior one runs downward from a point postero-ventral to postorbital spine and meets cervical groove in front of hepatic spine, about twice the length of anterior one. Marginal region ill-calcified, defined by finely marked pterygostomian carina. Abdomen sharply carinated along mid-dorsal line posterior to about middle of third somite, ending in an acute spinule in sixth somite; pleuron rounded on ventral edge except that of first and sixth somite, that of first somite minutely notched at about middle of inferior margin and that of sixth somite carries a fine spinule directed postero-ventraly near postero-lateral angle. Sixth pleonic somite bears no cicatrices, as long as wide, two-sevenths the length of carapace. Telson pointed, with a pair of immovable acute lateral spines at three-fourths and a well marked dorso-median groove which is lost near base of the spines, reaching tip of inner caudal swimmerets, a little less than half the length of carapace.

Eyes are of Type–C_2, rather large, reniform. Antennular peduncle hirsute, possesses prosartema which does not exceed apex of eye, and sharply pointed stylocerite streching as far as middle of first segment; basal segment has an acute spine somewhat surmounting its distal rim at antero-lateral angle; intermediate one cylindrical, ca. 1.7 times the width, about half the length of basal joint; the last one about as long as second one. Antennular flagella abruptly pointed (Fig. 94, *A*); upper flagellum seven-fifths the length of carapace, the lower one made up of 86 articles, slightly shorter than the upper, about twice the width of the upper. Basiserite has a small spine on distal outer edge. Scaphocerite reaches somewhat beyond tip of antennular peduncle, more or less narrowed anteriorly with rather narrowly rounded apex, thrice as long as wide measured at the broadest region; lateral rim almost straight with a stout distal spine which slightly exceeds far end of lamella. Carpocerite subcyrindrical, reaching a little behind middle of scaphocerite. Mandible V–shaped in inner aspect; molar process rather flat on masticatory surface which is somewhat lunate in outline; incisor one thin, with sharp cutting edge which has two acute teeth in its anterior half. Mandibular palp 2–jointed, foliaceous (Fig. 8, W); basal segment greatly dilated distally, (ca. 4. times as wide as proximal portion), about as long as wide; distal one subtriangular in outline with bluntly pointed apex, ca. 1.6 times the width. Maxillula belongs to Type–F_{1b}; endopodite acutly pointed, anterior margin bears an obtusely (ca. 130°) pointed protuberance directed outward at about middle, posterior margin slightly wavy except some basal portion where a rounded expansion is present (Fig. 94, *B*). Maxilla is of Type–G_1. First maxilliped belongs to Type–

H_{2a}; inner endites foliaceous, distal one suboval in outline, 2.4 times as long as wide; endopodite 5-segmented, ratio in length to the last joint: first 0.8, second 0.5, third 0.6, fourth 1.2, first segment compressed, suddenly dilated inward, with inner straight margin in four-fifths, intermediate 3 joints subequal in size, ca. 6 times as long as wide in penult segment, the last one ca. 11 times as long as wide, rounded at apex; exopodite rather narrow, ca. 7 times as long as wide, gradually tapers into a bluntly pointed tip anterior to its about two-thirds; inner border somewhat concave, and outer one almost straight in about two-thirds. Second maxilliped pediform, 7-segmented; basal two segments broader than long; ratios in length to dactylus: merus 2.3, carpus 0.9, propodus 0.6; merus subrectangular in outline, ca. 3.3 times as long as wide; carpus somewhat narrower than merus, rightangularly bent inwards; propodus as broad as long, equal to merus in length, directed backwards; dactylus slenderer than all others, ca. 25 times as long as wide, directed posteriorly with rounded apex. Third maxilliped also pediform, exceeds tip of antennal scale by some distal portion of propodus and entire dactylus, ratios in length to ultimate article: ishium 1.9, merus 1, carpus 1.5 and propodus 1.2. First cheliped reaching about half way of scaphocerite, armed with basal and ischial spines, proportions in length to movable finger: ischium (measured on upper surface) 0.9, merus 2,

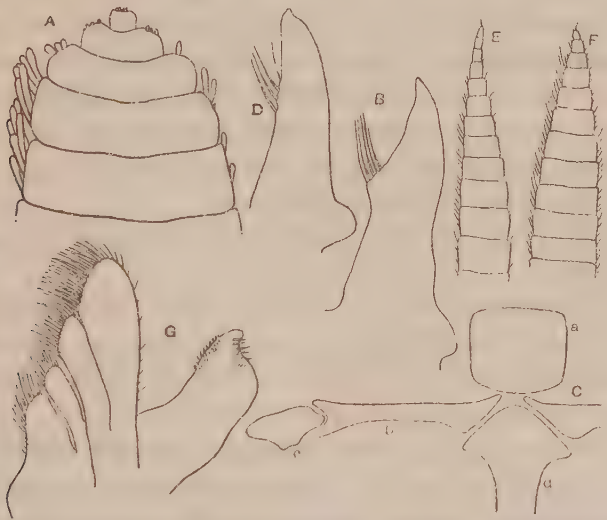

Fig. 94. *Solenocera alticarinata* (*A*–*C*) and *Solenocera prominentis* (*D*–*G*). *A* and *F*, tip of lower antennular flagellum; *B* and *D*, endopodite of maxillura; *C*, cardiac (a), pterocardiac (b), prezygocardiac (c), and anterior about half of urocardiac (d) ossicles; *G*, maxilla without exopodite. *A*, ×50; *B*, *D*–*G*, ×15; *C*, ×17.5.

carpus 1.9, palm 0.5; merus about 4 times as long as wide, equal to carpus in width; fingers of chela have almost straight cutting edges, devoid of armatures, with pointed tips. Second one extends beyond apex of scaphocerite by most part of chela, carries a basial spine, ratios in length to movable finger: ischium 1, merus 2.5, carpus 3.5, palm 0.5; merus ca. 5 times as long as wide; carpus a little diminishes in size distally; palm one and half times as long as wide, fingers somewhat slenderer than those of first leg. Third one reaches beyond tip of scaphocerite by about a third of carpopodite and entire chela, ratios to movable finger: ischium 1.1, merus 3, carpus 5.2, palm 0.7; ischium and merus subequal in size, about 7.5 times as long as wide in merus; carpus slenderer than that of second pereiopod, especially in distal half. Fourth pereiopod attains far end of second segment of antennular peduncle, ratios in length to dactylus, ischum 1, merus 2, carpus 2.3, propodus 1.5; ischium and merus subequal in size, ca. 4.5 times as long as wide; each segment distal to ischium succesively decreases in size toward tip, carpus ca. 10 times as long as wide, dactylus simply pointed. Fifth one much slenderer than any other, distal end of carpopodite reaches about middle of intermediate article of antennular peduncle; coxa provided with an acuminate spine attached to its antero-median surface; ischium, merus and carpus subequal in size, ca. 16 times as long as wide, the other segments mutilated.

All exopodites of thoracic appendages backward to second maxilliped equally small.

Thelycum is of Type-N_3, an inconspicuous subrectangular vertical plate present behind fourth limbs; posterior edge of the last thoracic sternite considerably elevated antero-ventrally with emarginate apex (Fig. 45, *E*).

Cardiac plate with 18-20 subequidistant spinules alined longitudinally (Fig. 80, *F*). Cardiac ossicle subquardrate, more or less wider than long, anterior and both lateral margins nearly straight but posterior one a little convex (Fig. 94, *C*). Pterocardiac bar shaped, anterior and posterior margins straight excluding both outer and inner subterminal portions, anteromedian angle produced into a pointed process pointing anteromedially, posteromedian angle also produced backward with bluntly pointed apex, and median edge lies posterolaterally, almost parallel to anterolateral margin of urocardiac ossicle; outer end subequally bifid with bluntly pointed tips (Fig. 94. C_b). Prezygocardiac small with irregular margins, about half the length of pterocardiac ossicle. Zygocardiac is of Type-R_4, armed on inner surface with a series of about nine rather sparsely set teeth arranged in a longitudinal row and diminishing posteriorly in size, and a tooth lying immediately below and as large as the foremost tooth of the series (Fig. 80, *F*). Urocardiac ossicle rather calcified, anterior about one third subtriangulary expanded with bluntly pointed apex. Prepyloric ossicle well calcified; distal portion posterior to three-fifths tapers into a point at an angle of ca. 60°, each lataral margin armed with about 10 acute spines (Fig. 72, *P* and *V*).

The foregoing description and figures are based on a female specimen, 65 mm in body-length, 21.8 mm in carapace-length, 5.1 mm and 9.2 mm in lengths of rostrum and telson respectively, secured from Tainan, Formosa by the Late Mr. Oo-U-Kijo, Dec. 27, 1936.

Note: The present species appears very near to *Solenocera hextii* WOOD-MASON (WOOD-MASON, 1891, p. 188 and p. 275, and ALCOCK, 1901, pp. 20, 21). But it may be easily distinguished from the latter by the characters tabulated in Table 17.

Table 17.

Items	Present species	*S. hextii* WOOD-MASON
1. Rostrum	horizontally straight; armed dorsally with 9 teeth (posterior 6 on carapace); attains about middle of basal segment of antennular peduncle.	ascending; dorsally armed until the level of basal joint of antennular peduncle
2. Antennular flagella	about seven-fifths the length of carapace.	about two-thirds the length of carapace.

Further, the present species is easily recognizable from all other species dealt with by the features of the characteristic postrostral crest and others as given in the key to the species of the genus, *Solenocera.*

Solenocera prominentis sp. nov.

(Figs. 8, *V*; 14, *C*; 16, *C*; 20, *M*; 27, *Q*~*S*; 45, *A*; 66, *G* and *H*; 72, *F* and *L*; 80, *E*; 94, *D*-*G*; 95; 100)

Body smooth, excluding narrow longitudinal tomentous region of each side of post-rostral carina anterior to the hindmost post-rostral spine, and also excluding similarly tomentous lateral surface above lateral carina of rostrum (Fig. 95). Rostrum rather short, slightly ascending, reaches a little beyond middle of basal segment of antennular peduncle; depth at base inclusive of spine about one-third the length; upper border straight, with 8 or 9 teeth, of which posterior 3 or 4 are found on carapace, first tooth placed at about mid-way between tip and the second, fifth stands a little in front of post-orbital margin or just above, the last one somewhat anterior to one-third of carapace, and 1.5 times as far distant from penult as penult from antepenalt, distances between other teeth get successively shorter anteriorly; lower border more or less convex, devoid of teeth. Post rostral carina markedly defined, extends to almost posterior rim of carapace, slightly indent a little anterior to middle of carapace, where each upper end of cervical groove is terminated. Anterior foot of hepatic groove slopes down into a minute semicircular concavity situated somewhat behind branchiostegal edge. Other elements found on carapace very closely resemble those of *Sol. alticarinata* in general aspect.

Abdomen dorsally carinated backward to a quarter of third segment. All pleonic pleura rounded on lower margins. Sixth pleonic somite has two spinules (one at posterior end of dorso-median carina, and the other near postero-lateral angle), ca. 1.3 times as long as wide, two-fifths the length of carapace. Telson pointed at tip, thrice as long as wide measured in the broadest region, a little more than half the length of carapace (or 1.4 times the length of sixth pleonic somite), provided with a pair of lateral immovable spines at four-fifths and a dorso-median groove which fades away at base of the spines.

Eyes large, reniform, well pigmented. Antennular peduncle 3-segmented, 1, 0.6, and 0.25 in relative length. Antennular flagella about 1.4 times as long as carapace, gradually tapering into a point in distal about 10 articles (Fig. 94, *E* and *F*), upper flagellum slightly longer but narrower (ca. 80%) than lower one. Basicerite possesses a minute stout spine on anterior outer margin. Scaphocerite rounded at apex, somewhat narrowed anteriorly, thrice as long as wide measured at the broadest region, reaching beyond far end of antennular peduncle by its about one-sixth, armed at antero-lateral angle with a small spine which is more or less exceeded by distal border of lamella. Carpocerite subcylindrical, attains a little in rear of middle of scaphocerite.

Mandible similar to that of *Sol. alticarinata*, but molar process flat on masticatory surface which is lunate in outline. Mandibular palp stretches to middle of third segment of antennal peduncle; basal segment invertedly deltoid, ca. 1.1 times as long as wide; distal one triangular, with bluntly pointed tip, 1.5-1.9 times as long as wide (Fig. 8, *V*). Maxillula well developed; endopodite unsegmented, distally narrows to a point, furnished with several long setae on anterior rim from middle to four-sixths, and bears an expansion with rounded apex near base of posterior edge (Fig. 94, *D*). Maxilla is of Type-G_1 (Fig. 94, *G*). First maxilliped closely resembles that of *Sol. alticarinata* in shape but not in relative dimensions of each joint of endopodite; first and fourth joints a little longer than the last one, second about a quarter, and third two-fifths the length of the last joint respectively. Second maxilliped pediform, inverted J-shaped; relative length: merus 2.6, carpus and propodus 0.7 to dactylus; merus about 4 times as long as wide. Third maxilliped reaching beyond tip of antennal scale by about half of dactylus, ratios in length to dactylus; ischium 2.5, merus and propodus 1.3, carpus 1.6; meropodite about 6 times as long as wide; dactylus simply pointed.

First pereiopod extends somewhat beyond far end of first joint of antennular peduncle, armed with a basial and ischial spines, thicker than third maxilliped, proportion in length to movable finger: ischium 1.2, merus 2.1, carpus 2, palm 0.5; each segment equal in width, ca. 6 times as long as wide in meropodite. Second cheliped attains distal end of scaphocerite, furnished with a basial spine, ratios in length to dactylus: ischium 1.4, merus 2.9, capus 4, palm 0.7; ischium and merus subequal in size, about 5.9 times as long as wide; carpus thinnest at about two-thirds and gradually gets thicker toward both ends, but thinner than merus. Third one surmounts distal end of scaphocerite by ca. one-fifth of carpus and entire chela, ratios in length against movable finger: ischium 1.6, merus 4, carpus 7, palm 0.5; both ischium and merus equal in size and slightly thinner than those of second pereiopod.

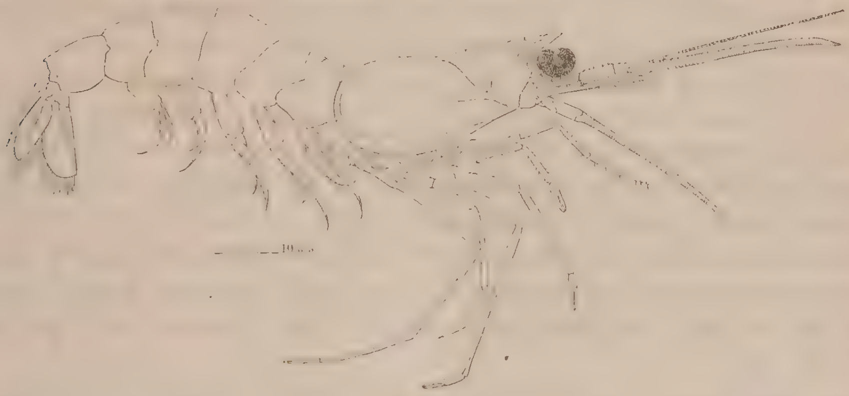

Fig. 95. *Solenocera prominentis*, sp. nov., male.

Fourth one extending distal end of intermediate joint of antennular peduncle, proportions in length to the last joint: ischium 1.4, merus 2.1, carpus 2.9, propodus 1.5; ischium and merus subequal in size, merus and carpus about 8 and 16 times as long as wide respectively. Fifth one exceeds far end of antennal scale by about half of propodus and entire dactylus, slenderer than all preceding pereiopods; coxa provided with a sharply pointed rather prominent stout spine directed fowards on anteromedian margin (Fig. 45, *A*); merus ca. 19 times as long as wide, a little shorter than carpus, but somewhat longer than propodus. Exopodite of first limb similar to those of second and third maxillipeds in configuration, hardly reaches far end of ischium, those of the following legs become successively smaller.

First abdominal appendage has a well calcified tubercle with rounded apex on inner surface just behind insertion of petasma. Second pleonic appendage of male triangularly swollen with rounded apex directed forward on outer surface of stalk (Fig. 95). Appendix masculina is of the type-O_{10}; the projection of proximal piece large, straight, blumtly pointed at apex, directed ventrally; distal outer and inner scales bill-like, with rounded apex, fringed with thickly set hairs on distal border, subequal in size and length, much larger than the projection lying on proximal piece, anterior margin of outer scale furnished with thickly set long hairs (Fig. 66, *G* and *H*).

Petasma is of Type-M_5. Median lobe considerably surpassing distal margin of lateral lobe, provided with about 13 setae on distal edge of its ventral lobule (Fig. 27, *R*). Lateral lobe devoide of setae, rounded at far end of its ventral lobule. Process-*a* stands at about middle of ventral edge of lateral lobe, very long and stout, extending to eight-ninths of lateral lobe directed somewhat antero-medially, about 5 times as long as wide, strongly curves sidewise at apex which is serrated with about 15 fine setae (Fig. 27, *Q*-*S*, *a*). Process-*b* minute, sharply pointed, directed forward, placed slightly backward to midway and near free lateral margin of lateral lobe (Fig. 27, *S*, *b*). Thelycum rather simple. A stout median transverse plate with somewhat emarginate apex laid down close anterior edge of the last thoracic sternite. The hindmost thoracic sternite has in its posterior half a flat quadrate area, bounded by anterior and lateral low and short ridges, as well as by thick and much elevated, posterior ridge which runs the entire width of the sternite and appears trapezoidal in posterior view, with straight lateral margins and concave apex, sloping rather steeply both forward and backward (Fig. 45, *A*).

Cardiac plate armed on inner surface with about 17 spinules arranged equidistantly in a longitudinal row (Fig. 80, *E*). Cardiac, pterocardiac and prezygocardiac ossicles closely resembles those of *Solenocera alticarinata.* Urocardiac broad, with rounded anterior rim and a pair of rather bluntly pointed lateral processes directed sidewise in anterior subterminal portion (Fig. 72, *L*). Zygocardiac carries on inner surface a longitudinal series of 11 closely set pointed teeth which become somewhat smaller rearward, and also one tooth which is as large as the foremost one of the above mentioned series situated immediatly below the first tooth of the series; ventral margin well calcified, remarkably upheaved with rounded apex, bearing rather sparsely set short setae (Fig. 80, *E* and *E'*). Prepyloric elongated, pentagonal in upper aspect, tapering posteriorly into one terminal tooth, armed on each postero lateral edge with 8-10 acuminate teeth which become gradually larger backward but even the rearmost one about half the size of the terminal tooth (Fig. 72, *F.* and *L*).

The description and figures given above are mostly based on a male,

Table 18. Measurments (in mm) of bodily parts and counts showing variation of *Solenocera prominentis*. *A*, length of sixth pleonic segment; *B*, length of telson; *RL*, body length; *C*, length of antennal scale; *CL*, carapace length; *D*, length of longer antennular flagellum; *Max.*, length of third maxilliped; *RL*, length of rostrum.

No.	Sex	BL	CL	RL	A	B	C	D	D/CL	Max.	1st	2nd	3rd	4th	5th	No. rost. spines
1	♂	98.5	26.0	8.9	11.6	15.2	18.0	35.7	1.37	35.1	27.0	41.3	56.6	42.7	63.4	3+6=9
2	"	96.0	26.0	9.0	11.8	16.6	18.7	38.0	1.46	37.5	28.0	—	—	45.6	—	3+5=8
3	"	81.0	22.1	7.4	9.8	13.0	15.6	31.5	1.42	—	20.2	36.5	50.0	39.4	—	3+5=8
4	"	74.5	20.0	6.5	9.5	12.0	13.9	30.0	1.50	29.1	22.2	—	—	35.5	52.3	3+5=8
5	"	64.8	18.0	—	8.4	10.6	12.8	26.1	1.45	26.5	20.5	30.5	41.9	33.7	50.2	3+——
6	♀	111.0	33.5	10.2	13.4	18.0	21.0	—	—	45.5	35.0	54.5	78.0	57.0	80.2	4+4=8
7	"	107.5	32.5	10.0	13.2	18.0	21.6	38.7	1.19	42.2	33.0	—	—	55.8	—	3+5=8
8	"	98.2	30.0	8.5	11.9	16.0	—	35.3	1.17	41.0	31.5	48.5	65.0	—	—	4+4=8
9	"	—	29.1	9.8	11.1	—	19.2	36.5	1.25	41.0	32.0	50.5	62.0	52.0	—	4+5=9

81.0 mm long (22.1 mm in carapace-length) obtained from Kumanonada, off Owase, Mie Pref. at a depth of about 350 m. Besides the type specimen, 4 males and 4 females, measuring 64.8~111.0 mm long (18.0~33.5 mm in carapace length) were also examined, collected from Kumanonada, Heta (Sizuoka Pref.), Tatsuga-hama (Wakayama Pref.) (150~400 m).

Note: The spines beset on upper rostral border and post rostral carina are 8 or 9, mostly 8 (6 specimens out of 8 bearing complete rostrum have 8 spines) in number. Of the 8 specimens, 3 are found having 4 armatures on carapace, and the rest carrying 3 (Table 18). In the former case, the posterior fourth spine is always situated just behind the post-orbital margin, whilst in the latter case, the antepenult one is found without exception standing as far backwards from frontal border about half of the distance between antepenult and the posterior fourth spines. The longer antennular flagellum varies in proportion of length to that of the carapace from 1.37 to 1.50 in male and from 1.17 to 1.25 in female. Thus it seems that the apperatus of male is relatively longer than that of the other sex (Table 18).

The species newly proposed herewith closely resembles *Solenocera melantho* DE MAN (1911, pp. 48–52, Pl. 5, figs. 12 and 12. *a–i*). But the former may easily be separated from the latter by longer pereiopods and characteristic petasma as given in the following table (Table 19).

Table 19.

	Items	Present species	*Solenocera melantho* de Man
1	1st pereiopod	carpus slightly shorter than merus; finger about two times the length of palm; chela about 3.7 times the width.	carpus a little longer than merus; finger 2.5 times the length of palm; chela usually more than 4 times the width.
2	2nd pereiopod	reaches far end of antennal scale; carpus 2.7 times the length of chela.	projects with one-fourth or one-fifth of its calpal joint beyond antennal scale.
3	3rd pereiopod	extends beyond antennal scale by one-fifth and entire chela.	extends with more than half of carpus and entire chela.
4	4th pereiopod	attains about three-fourths of antennal scale.	reaches by its dactylus beyond antennal scale.
5	5th pereiopod	exceeds distal tip of scaphocerite by about half of propodus and entire dactylus.	reaches with two last joints beyond scaphocerite.
6	Petasma	distal margin of lateral lobe devoid of setae.	distal margin of lateral lobe furnished with many (12~13) fine setae.

Solenocera depressa sp. nov.

(Fig. 8, *R*; 27, *T*∼*V*; 45, *B*; 66, *E* and *F*; 72, *O* and *U*; 80, *G*; 96; 98, *A*∼*D*; 100)

Carapace, abdomen, tail fan, eyes and antennular peduncle closely resemble those of *Sol. prominentis* in general configuration.

Antennular flagella subequal in length, a little less than twice the length of carapace. Antennal scale strikingly similar to that of *Sol. alticarinata* and *Sol. prominentis* in shape, reaching to or slightly beyond far end of antennular peduncle.

Mandible also similar to that of *Sol. alticarinata* and *Sol. prominentis* in general feature and even proportional items of palp. (Fig. 8, *R*). Maxillula is of type-F_{1b}; endopodite unsegmented, bluntly pointed at apex, more or less bent anteriorly in distal one-sixth; anterior margin bears several long hairs a little sidewise to middle; posterior one has a semicircular projoction near base (Fig. 98, *C*). Maxilla very intimately related to that of *Sol. prominentis.* First maxilliped bears suboval inner distal endite, five-segmented endopodite and rather narrow exopodite, all of which are similar to those of *Sol. alticarinata* and *Sol. prominentis;* ratios of each component joint of endopodite in length to the last joint; first 1.3, second and third 0.5, fourth 11. Second maxilliped seven-jointed, proportions in length to dactylus: merus 2.5, carpus 0.7, propodus 0.6; meropodite rectangular in outline, about three and half times as long as wide; dactylus rounded at apex, ca, 2.4 times the width. Third maxilliped reaches beyond far end of antennal scale by at least entire dactylus, relative dimensions: ischiopodite 1.8, meropodite and dactylopodite 1, carpopodite 1.1 and propodite 0.9; meropodite five times as long as wide, dactylus simply pointed.

First pereiopod armed with a basial and an ischial spines, stretching to about two-thirds of intermediate article of antennular peduncle, ratios in length against movable finger: ischium 1.1, merus 2, carpus 1.9 and palm 0.5. Second one exceeds tip of scaphocerite by half of chela, bearing a basial spine; meropodite about five times as long as wide, twice the length of ischium, two-thirds as long as carpus which is ca. 12 times as long as wide, and 1.5 times the length of chela; movable finger 1.4 times as long as palm. Third one reaches beyond distal end of antennal scale by about one-fifth of carpus and entire chela, proportions in length to movable finger: ischium 1.4 (measured anteriorly), merus 3.1, carpus 5.8 palm 0.8; merus about 8 times as long as wide; carpus markedly thin in distal half, the thinnest portion about half as wide as proximal portion which is as broad as merus. Fourth one extends a little beyond distal end of second segment of antennular peduncle; ischium 1.1, merus 1.9, carpus 1.2 and propodus 1.4 times the length of dactylus respectively; merus ca. 6 times as long as wide. Fifth one surmounts distal margin of antennal scale by half of propodus and entire dactylus, ratios in length to the last segment: ischium 1, merus 2.5, carpus and propodus 2.6; coxa has a small acute spine directed forwards on antero median surface. Chelae, and exopodites attached to thoracic appendages posterior to first maxilliped closely allied to those of *Sol. prominentis.*

First abdominal appendage has a protuberance just behind insertion of petasma, and second one provided with a triangular prominence on outer surface of peduncle as in *Sol. prominentis.*

Appendix masculina is of Type-O_{10}; outer process of basal piece rounded at apex, directed ventrally, considerably thicker and longer than that of *Sol. prominentis;* distal piece consists of outer and inner scales, outer scale furnished along distal margin only with short setae directed inward, somewhat smaller than inner one; inner scale with rather long and thickly set hairs along distal and anterior margins, about 1.7 times the process set on basal piece (Fig. 66, *E* and *F*).

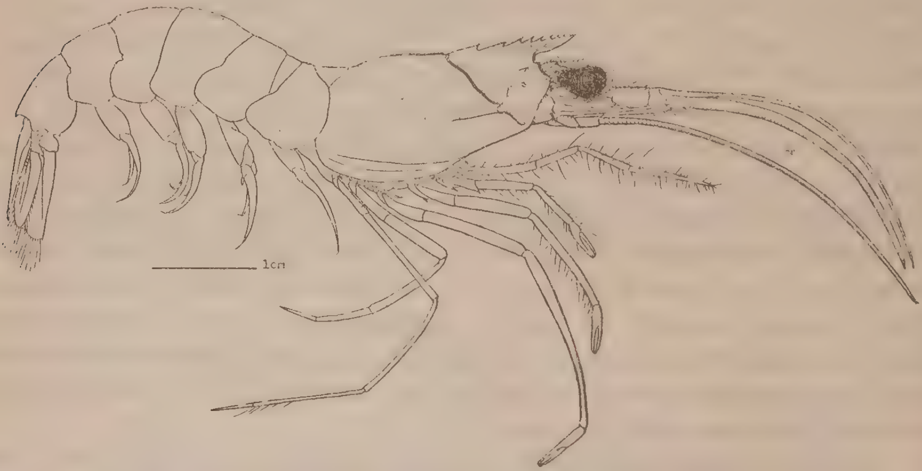

Fig. 96. *Solenocera depressa,* sp. nov., male, without petasma.

Petasma very similar to that of *Sol. prominentis*, but differs as follow: distal edge of median lobe fringed with about 18 sharply pointed setae; anterior rim of lateral lobe furnished with 14∼16 setae; spatulate projection provided along distal margin with 15 minute setae; and process-*b* absent (Fig. 27, *T–V*).

Thelycum again closely resembles that of *Sol. prominentis.* A small transverse plate present on sternite between fourth pereiopods. The low ridges bounding quadrate area lying on the last thoracic sternite a little more salient than those of the species in question, the anterior ridge almost reaching to postero-median margins of fourth pereiopods. Posterior edge of the hindmost thoracic sternite elevated, but much less pro-

Table 20. Dimensions (in mm), proportion and count of body-parts of *Sol. depressa*. *A*, length of sixth abdominal segment; *B*, length of telson; *BL*, length of body; *C*, length of antennal scale; *CL*, carapace-length; *D*, length of antennular flagella; *Max.*, length of third maxilliped; *RL*, length of rostrum; *, located on carapace.

No.	Sex	BL	CL	RL	A	B	C	D	D/CL	Max.	Length of pereiopods					No. rost. spines
											1st	2nd	3rd	4th	5th	
1	♂	57.5	16.2	4.4	7.0	9.5	11.0	30.0	1.85	24.5	17.8	26.0	38.5	27.5	41.0	*3+6=9
2	♀	76.0	22.0	5.1	8.8	11.9	13.5	—	—	—	24.5	36.5	54.0	39.0	—	3+4=7
3	”	67.0	19.5	5.0	8.5	10.4	12.0	—	—	29.6	21.5	33.5	—	—	—	4+4=8
4	”	63.0	18.4	4.5	7.8	9.9	11.5	32.8	1.78	27.3	19.3	30.0	42.1	31.9	45.4	4+4=8
5	”	58.2	17.5	—	7.1	9.7	11.9	33.5	1.91	—	19.0	27.7	42.2	30.0	—	3+——
6	”	55.1	16.1	4.0	6.9	9.1	10.4	30.0	1.86	24.2	18.8	27.0	40.0	—	43.0	4+4=8

minent than that of *Sol. prominentis* with somewhat sinnuate apical margin (to which the specific name is referred) (Fig. 45, *B*).

Cardiac, pterocardiac and zygocardiac ossicles similar to those of *Sol. alticarinata.* Cardiac plate armed with about 12 spinules (Fig. 80, *G*). Urocardiac one appears much alike to that of *Sol. prominentis*, distance measured from tip to tip of anterior subterminal processes about 2.8 times the width measured at middle of this ossicle (Fig. 72, *O*). Zygocardiac resembles that of *Sol. prominentis*, but the longitudinal series made up of 9 teeth (Fig. 80, *G*). Prepyloric carries about 9 teeth on each postero-lateral edge (Fig. 72, *O* and *U*).

The description and illustrations given above are based on a male, 57.5 mm. long (16.2 mm in carapace-length), secured from Kumanonada, off Owase, Mie Pref. In addition to the type specimen, five females, measuring 55.1～76.0 mm long (16.1～22.0 mm in carapace-length), obtained from the same locality and Nagasaki were examined.

Note: The number of upper rostral spines ranges from 7 to 9. Of the present specimens, except a female with rostrum broken off, one has 7, three have 8 and one has 9. The spines lying on post rostral carina are 3 or 4 in number.

The antennular flagella are 1.85 times the length of carapace in a male (type specimen), and 1.78～1.91 in the three females (Table 20). From such fact, it may be mentioned that this organ of the present species exhibits no sexual modification at least in length.

The antennal scale reaches about far end of the antennular peduncle as in *Sol. distincta* (DE HAAN, 1850, p. 194, and DE MAN, *op. cit.*, pp. 51-52) and *Sol. koelbeli* (DE MAN, *loc. cit.*, p. 51), measuring 10.4-12.0 mm in length so far as the present investigations go, however, not extending beyond the distal tip of the peduncle as that of *Sol. prominentis.* So that, this trait may afford an important criterion for distinction of these species.

The species newly erected in this place very closely allied to *Sol. melantho* (DE MAN, *op. cit.*) and the preceding species, *Sol. prominentis*, especially to the former. But the present species may be easily distinguished from the former by having longer antennular flagella, 1.78～1.91 times as long as carapace instead of being about one and half times, and shorter antennal scale (reaching tip of antennular peduncle) and all the pereiopods which are nearly the same as thos of *Sol. prominentis* in relative dimensions. *Sol. prominentis* may differ from the latter in the following respects, viz, (1) longer antennular flagella and shorter antennal scale as given above, (2) spur-like process of the proximal piece of the appendix masculina thicker and shorter, (3) petasma furnished with 14-16 setae on distal margin of lateral lobe, (4) posterior edge of the last thoracic sternite less elevated, and (5), coxal process of fifth preeiopod of female much smaller.

Solenocera faxoni De Man

(Figs. 8, *U*; 20, *P*; 27, *C–E*; 45, *F*; 66, *A* and *B*; 72, *R* and *X*; 80, *C*; 97, 98, *E*~*G*; 100).

Solenocera faxoni, De Man, 1911, pp. 52~53, pl. 5, fig. 13.

Shell glabrous, except tomentous lateral surfaces of rostrum and such surfaces near base of it. Rostrum horizontal, lanceolate in profile, reaching somewhat behind distal margin of first segment of antennular peduncle, about one-fifth the length of carapace; upper border armed with 6 teeth, of which posterior 4 located on carapace, first one stands at about mid-way, third one above post-orbital margin, the last one at one-third of carapace and at about twice as far distant from penult tooth as penult from antepenult; lower border devoid of teeth. Post-rostral carina extending about middle of carapace. Cervical and hepatic grooves clearly cut, the former slopes up nearly to end of post-rostral carina, and the latter reaches slightly behind the level vertical through upper end of cervical groove and meets with ill-defined branchio-cardiac and inferior grooves. Orbito-antennal groove barely defined. Aanterior and posterior indistinct vertical grooves present; the former is found a little in front of hepatic spine, meeting with cervical groove in its inferior end and the latter arises a little in advance of crosspoint of hepatic, branchio-cardiac and inferior grooves, and runs antero-dorsally reaching nearly below cervical groove. Post-orbital, antennal, hepatic and branchiostegal spines present. Post orbital subequal in size to hepatic one, but somewhat larger than antennal one. Branchiostegal spine characteristically broad, arising immediately behind lower margin of anterior foot of hepatic groove and overlaps a part of the groove and pterygostamian margin. Orbital angle not spinous.

Abdomen dorsally carinated backward to third somite; third somite more or less swollen with no trace of median carina in posterior half of tergum, and deeply incised on posterior dorso-median edge; fourth and fifth segments also incised like the third and minutely notched at middle of posterior rim of each lateral shell; sixth one has a spinule at distal end of dorsal carina and another one at each postero-lateral angle, about 1.8 times as long as wide, two-fifths the length of carapace; pleuron of first segment minutely excavated at two-thirds of inferior rim. Each pleonic sternite anterior to fifth one has a short stout pointed median process directed antero-ventrally, but it becomes gradually smaller in size posteriorly. Telson elongated triangular in upper aspect, bearing a pair of immovable spine at about two-thirds and a shallow dorso-median groove, reaching to or beyond tips of inner caudal appendages, about half as long as carapace.

Eyes attain a little behind distal end of first segment of antennular peduncle, remarkably smaller than those of all preceding species of *Solenocera*. Stylocerite extending to two-thirds of basal antennular segment. Antennular flagella subequal in length, 1.15–1.18 times the carapace; upper one flat on both inner and outer surfaces, about 0.5 mm broad in subterminal portion, abruptly narrowed into a filament consisting about 10 articles (Fig. 98, *E*); lower one concavo-convex, composed of ca. 47 articles, about 0.6 mm wide in sixth article from apex, abruptly pointed, with last two articles very minute (Fig. 98, *F*). Basicerite has a small but stout spine at about middle of anterior outer rim. Antennal scale ca. 3 times as long as wide measured at the widest region, surpassing tip of antennular peduncle by about one-eighth of its length; disto-lateral spine exceeded by narrowly rounded margin of lamella. Carpocerite cylindrical, reaching slightly beyond middle of intermediate joint of antennular peduncle.

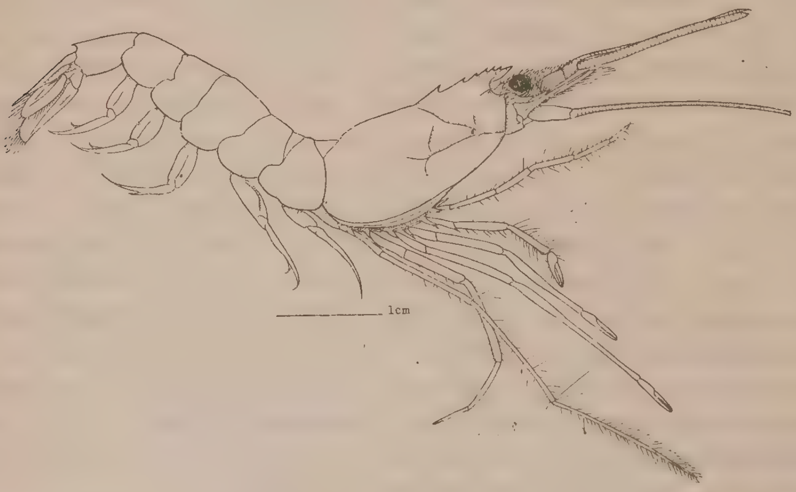

Fig. 97. *Solenocera faxoni* De Man, male, without petasma.

Mandible V–shaped in inner aspect, molar process with flat masticatory surface which is oval in outline; incisor one unarmed on cutting edge, much thinner than molar process. Mandibular palp stretches to fourth segment of antennal stalk; basal segment markedly excavated on inner side, as long as wide measured at the broadest region; distal one deltoid in outline with rounded apex, ca. 1.6 times as long as broad measured at the widest region, ca 1.8 times the length of basal joint (Fig. 8, *U*). Maxillula belongs to Type–F_{1b}; endopodite unsegmented, with narrowly rounded apex, anterior edge somewhat wavy with a small number of long setae in distal half, posterior one nearly straight with a rather broadly rounded swelling at base (Fig. 98, *G*). Maxilla similar to that of *Sol. depressa.* First maxilliped is of type-H_{2a}; inner distal endite ogival in outline, thrice the width; endopodite 5-jointed, ratios in length to the last joint: first segment 2, second 0.4, third 0.5, fourth 1; exopodite rather narrow, tapering into a point in anterior one quarter, but rounded on posterior rim. Second maxilliped 7-segmented, proportions in length to dactylus: merus 2.5, carpus 0.7, propodus 0.5; first three articles very short, broader than long; meropodite ca. 4.3 times as long as wide; dactylus twice as long as wide, rounded at apex which is beset with several large stout setae besides numerous hairs. Third maxilliped reaches beyond tip of antennal scale by entire dactylus; ischium equal to carpus in length, 1.8 times the length of the last joint; merus and carpus equal in length, 1.4 times as long as dactylus which is simply pointed.

First cheliped extending far end of second joint of antennular peduncle, armed with both basial and ischial spines, ratios in length against movale finger: ischium 1, merus 2, carpus 1.9, palm 0.5; merus about 6 times as long as wide; fingers of chela have unarmed, nearly straight prehensile edges and simply pointed tips. Second one somewhat exceeding distal end of scaphocerite, carries a basial spine, as thick as preceding cheliped, proportions in length to ductylus: ischium 1, merus 2.2, carpus 3.2, palm 0.6. Third one surmounts apex of antennal scale by subterminal portion of carpopodite and entire chela, ratios in length to movable finger: ischium 1.2, merus 3.3, carpus 5.9, palm 0.7; merus ca. 11 times as long as wide, about twice the width measured at distal three-fifths of carpus. Fourth pereiopod reaches distal end of antennal scale; ischium 1, merus 1.6, carpus 2.2, propodus 1.4 in proportion to dactylus. The last pereiopod stretches beyond tip of antennal scale by about one-third of propodus and entire dactylus, thinner than all other thoracic limbs, ratios in length to dactylus: ischium 0.7, merus 2, carpus 2.6, propodus 2.7; distal two segments with rather long and thickly set fine hairs.

Exopodite of second maxilliped attains about midway of merus, that of third maxilliped somewhat beyond far end of ischium. But that of first pereiopod reaches about half-way of ischium. That of the following pereiopods succesively becomes smaller.

First and second pleonic appendages of male are equal to those of *Sol. prominentis* and *Sol. depressa* in possession of a well calcified protuberance and a triangular swelling on stalk.

Appendix masculina well developed. The spur-like projection of proximal piece rather thin, bluntly pointed at apex, directed ventrally. A tubercle with rounded apex present at about center of posterior surface of proximal piece. Distal two scales elongated, triangular, concavo-convex with each convex surface outward; inner one fringed with rather long and thickly set hairs along anterior outer and terminal margins, outer one completely hidden behind the other in inner aspect, about twice the length of the spur-like process of proximal piece (Fig. 66, *A* and *B*).

Petasma: median lobe extending beyond tip of lateral lobe by about one-eighth, fimbriated with about 15 sharply pointed setae directed sidewise along outer half of distal margin and lateral margin anterior to far end of lateral lobe. Lateral lobe furnished on outer edge of distal one-fourth with 33 acute fine setae pointing outward, of which subterminal several ones much larger than others (Fig. 27, *C–E*). Process–*a* arises from about middle of ventral free margin of each lateral lobe, reaching a little behind apex of lateral lobe, strongly curves laterally near apex with minutely wavy apical margin (Fig. 27, *D*). Process–*b* situated at about six-sevenths of lateral lobe, appears as a lamellate subrectangular (ca. twice as long as wide) strip with rounded apex bearing two or three pointed setae, directed forwards (Fig. 27, *D* and *E*). Thelycum very simple, without any conspicuous projections and even upheavals (Fig. 45, *F*).

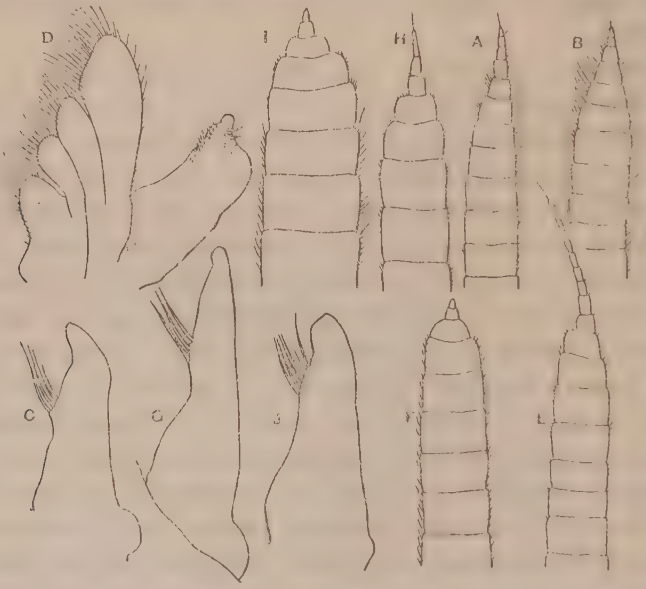

Fig. 98. *Solenocera depressa* (*A–D*), *Solenocera faxoni* (*E–G*) and *Solenocera brevipes* (*H–J*). *A*, *E* and *H*, terminal portion of upper antennular flagellum; *B*, *F* and *I*, terminal portion of lower antennular flagellum; *C*, *G* and *J*, endopodite of maxillula; *D*, maxilla without exopodite. *A–F*, ×15; *G* and *J*, ×20; *H*, and *I*, ×25.

Cardiac plate with 18–20 equidistant spinules arranged in a longitudinal row extending almost its entire length (Fig. 80, *C*). Urocardiac ossicle composed of proximal triangular part and distal rectangular part, the former with acute (ca. 60°) apex and base 2.5 times as broad as the latter which is twice as long as the former (Fig. 72, *R*). Zygocardiac has one upper and one lower tooth, each equally large and acute on anterior rim, upper one followed by five acuminate smaller teeth alined longitudinally; ventral margin well calcified, markedly raised ventromedially with broadly rounded apex (Fig. 80, *C*). Prepyloric has 8 or 9 rather slender acute teeth on each postero-lateral edge (Fig. 72, *R* and *X*). Lateral wall of pyloric chamber carries a tooth as large as penult one of the longitudinal series of zygocardiac ossicle at a distance posterior to the last tooth of the series (Fig. 80, *C*).

Aforementioned description and Figs. 97 and 98 are based on a male and a female, 50.0 mm and 49.3 mm long (14.8 mm and 15.2 mm in carapace-length) respectively. Another female, 48.8 mm long (16.1 mm in carapace-length) was also examined.

Locality: Kumanonada (ca. 250 m), off Owase, Mie Pref.

Distribution: Near Kei Islands (310 m) (De Man).

Note: The present species has never been put on record since De Man (*op. cit.*), so far as the writer is aware.

De Man's description was based on a much mutilated female specimen, missing the antennal flagella, third maxillipeds and thoracic limbs, obtained near Kei Islands. The present three specimens well tally with De Man's description and illustrations. Only descrepancy is found in the width of antennular flagella. The appartus of the present specimens somewhat narrower than those of De Man's *Sol. faxoni*, being in subterminal portion, 0.5 mm and 0.6 mm broad in upper and lower flagella respectively, instead of being equally 0.7 mm wide in the tatter species. But it appears to be merely a deviation within apecies. Thus the specimens on hand may be referred to the species in question.

Upper rostral spines are found 6 or 7 in number, of which the posterior 3 or 4 are situated on carapace as in *Sol. prominentis* and *Sol. depressa*.

The presence of the following features is peculiar to the present species comparing with all the preceding species of *Solenocera*, viz., (1) ill-defined vertical groove running upward from a point slightly in front of the posterior end of hepatic groove, (2) large depressed flat branchiostegal spine, (3) unarmed incisor process of mandible, (4) anterior quarter of lateral margin of lateral lobe of petasma fimbriated with numerous fine setae, and process-*b* of the organ rather large bearing two or three minute setae on appical margin, and (5) simply flat thelycum.

Solenocera brevipes sp. nov.

(Figs. 1, *S*; 8, *X*; 20, *N*; 27, *F–H*; 45, *D*; 66, *I* and *J*; 72, *Q*; and *W*; 80, *A*; 98, *H–J*; 99; 100).

Closely resembles *Sol. prominentis* as well as *Sol. depressa* in general form.

Rostrum short, horizontal, and reaches about one-fourth of basal segment of antennular peduncle, measuring about one-fifth the length of carapace; upper border straight with 5 teeth, first one of which situated a little nearer to second tooth than to tip, third one inserted above frontal margin of carapace, the fifth one at a quarter of carapace, separated from the fourth twice the distance between the fourth and the third; lower border toothless, markedly convex. Carapace provided with postorbital, antennal, pterygostomian and hepatic spines. Postrostral carina extends to about middle of carapace. Cervical groove slopes up reaching to posterior end of postrostral carina. Hepatic gently slopes up behind pterygostomian angle, and then turns horizontally below hepatic spine to reach under the end of cervical groove, furnished with sharply defined lower or posterior rim in anterior arm only. Orbito-antennal groove hardly marked. Branchio-cardiac not recognizable. Supra-orbital angle defined but not spiniform. Pleon intimately resembles that of *Sol. faxoni*, but dorso-median carina commences from about middle of third segment in which it is not sharply defined, and sixth segment one and half times as long as wide. Each anterior 4 pleonic sternite has a median process as is the case with *Sol. faxoni*. Telson tapers into an acuminate tip, provided with a pair of inmovable acute lateral spines at about three-fourths and a clearly cut dorso-median groove lost near base of the spines, surmounted a little by tip of inner uropod, 2.7 times as long as wide measured at the widest region, somewhat less than half the length of carapace, more or less longer than sixth abdominal somite.

Eyes reaching six-sevenths of first segment of antennular peduncle, larger than those of *Sol. faxoni*, but rather smaller than those of *Sol. prominentis* and *Sol. depressa*. Antennular peduncle hirsute, first joint 1, second 0.5, third 0.3 in relative length. Stylocerite extending a little beyond half-way of basal segment of antennular peduncle. Antennular flagella about 1.5 times as long as carapace; upper one almost flat on both inner and outer surfaces, ca. 0.36 mm wide in eight article from tip, abruptly narrowed distally from the last article but four (Fig. 98, *H*); lower one shorter and broader than the other, ca. 0.5 mm broad in seventh joint from far end, but tipped with last two very minute articles (Fig. 98, *I*). Basicerite has a small spine on anterior outer border. Antennal scale attains a little beyond tip of antennular peduncle, two and half times as long as wide measured at the broadest region, gradually narrowed distally to a rather narrowly rounded apex produced as far as acute tip of straight outer edge, about three-fifths the length of carapace. Carpocerite extends two-fifths of the scale.

Mandible: molar process with almost flat masticatory surface and pointed postero-median masticatory edge; incisor one has two bluntly pointed teeth in anterior half of cutting edge. Mandibular palp stretching to fourth segment of antennal stalk; basal joint invertedly subtriangular in outline, ca. 1.3 times as long as wide measured at the widest region; distal one tapering and rounded at tip, about 2.3 times as long as wide, and as long as proximal one (Fig. 8, *X*). Maxillulary palp foliaceous, gradually narrowed distally ending to a bluntly pointed tip, carries a small number of long setae in subterminal anterior rim (Fig. 98, *J*). Maxilla is of Type–G_1. First maxilliped resembles that of *Sol. faxoni* in general aspect; inner distal endite about 2.5 times as long as wide; endopodite five-jointed, ratios in length to the last article: first 1.7, second and third 0.5, fourth 1.1; exopodite about 7.5 times the width. Second maxilliped pediform, ratios in length to dactylus: merus 2.9, carpus and propodus 0.8; merus quadruple as long as wide; dactylus twice the width, bluntly pointed at apex, with several spinous bristles besides thick set of hairs. Third maxilliped extends beyond antennal scale by one-sixth of propodus and entire dactylus, ratios in length to dactylus: ischium 1.9, merus and propodus 1.5, carpus 1.7; merus about 5 times the width; dactylus simply pointed.

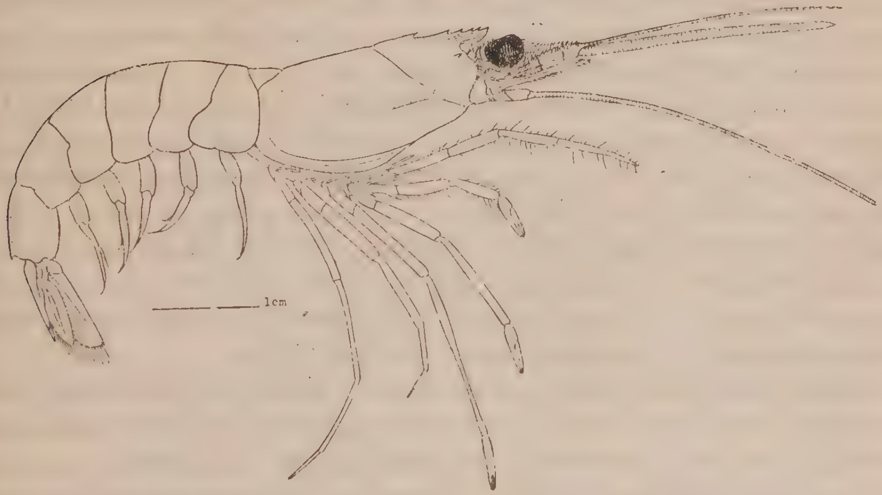

Fig. 99. *Solenocera brevipes*, sp. nov., 55.0 mm in body-length (16.8 mm in carapace-length), female.

First pereiopod reaches far end of second article of antennular peduncle, furnished with both basial and ischial spines; merus and carpus subequal in length as well as in size, 4.5 times the width, and twice the length of ischium or 1.6 times the length of movable finger which measures twice the length of palm. Second one reaches to or beyond distal tip of antennal scale, bearing a basial spine only; ischium 1, merus 2.1, carpus 3.2, palm 0.6 in relative length to dactylus; merus 5.5, and propodus 12 times as long as wide respectively. Third one exceeds scaphocerite by a fifth of carpus and entire chela, proportions in length to movable finger: ischium 1.2, merus 3.5, carpus 6, palm 1; coxa carries a rather markedly developed projection on postero-median surface; merus about 10 times as long as broad, as thick as ischium, slightly thicker than the thickest portion of carpus. All chelae have nearly straight unarmed cutting edges and simply pointed tips. Fourth pereiopod attains distal extremity of first segment of antennular peduncle; coxa furnished on posteromedian surface with a small somewhat lamellate process which is rounded at apex and directed posteromedially; merus ca. 5 times as long as wide, equals to carpus in length, twice the length of dactylus which measures 0.9 times the length of propodus, 1.5 times and 2.5 times the width of carpus and propodus respectively. Fifth one reaching beyond far end of antennal scale by about half of dactylus, proportions in length to dactylus: ischium 0.9 merus 2.1, carpus 2.5, propodus 2; merus ca. 11 times as long as wide, twice the breadth of propodus; coxa has a narrow transverse projection on inner surface (Fig. 45, *D*); dactylus simply pointed at tip.

First pleonic appendage of male has a minute process behind base of petasma, and second one a triangular upheaval on outer surface of its stalk as in *Sol. prominentis*, *Sol. depressa* and *Sol. faxoni*.

Appendix masculina belongs to Type-O_{10}; the projection of proximal piece remarkably developed, directed obliquely outwards, strongly curved dorsally in subterminal portion, bluntly pointed at apex; distal two scales concavo-convex, with convex surface sidewise, broadly rounded at apex, subequal in size, furnished with rather long thickly set hairs along anterior margin of inner scale, and with short setae along distal edge of the other (Fig. 66, *I* and *J*).

Petasma: dorsal lobule of median lobe minute and simply rounded at apex (Fig. 27, *F* and *H*). Ventral lobule of median lobe greatly (ca. a quarter of the length) surmounts apex of dorsal lobule of the lobe, provided with a striking apical projection which is remarkably expanded, oval in outline, marginally rather thickened, somewhat recurved anterolaterally, with numerous acute setae along entire margin, and entirely surpassing apex of lateral lobe. Ventral free margin of lateral lobe strongly bent sidewise and fringed with many sharp setae almost in distal third. Process–*a* large, inserted at about three-fifths of ventral free margin of lateral lobe, reaching to four-fifths of the margin, broadly rounded and bare at apex. Process–*b* absent.

Thelycum rather intricate. Penult thoracic sternite has a low longitudinal median elevation in posterior half. The last thoracic sternite transversely embossed with emarginate posterior margin near anterior edge, and has a rather prominent transverse upheaval at middle; posterior edge simple, gently slopes forward (Fig. 45, *D*).

Cardiac plate armed with about 16 spinules arranged in a longitudinal row along its entire length (Fig. 80, *A*). Cardiac, pterocadiac, and prezygocardiac ossicles very closely resemble those of *Sol. alticarinata*. Zygocardiac one furnished with one longitudinal series of about 8 closely set pointed stout teeth which get gradually smaller backward, and with a tooth which is as large as the first one of the above series, and situated immediately below it (Fig. 80, *A*). Urocardiac obtusely pointed lateral processes near anterior end (Fig. 72, *Q*). Prepyloric has about 9 pointed teeth on each disto-lateral margin (Fig. 72, *Q* and *W*). Lateral wall of pyloric chamber carries a tooth somewhat behind the last tooth of the series of zygocardiac ossicle.

The aforementioned description and figures are based on a female, 55 mm long (16.8 mm in carapace-length), and a male, 50.8 mm long (14.1 mm in carapace-length), obtained from Kumanonada (ca. 300 m in depth) off Owase, Mie Pref. by Mr, G. ABE. Besides these, 7 males, ranging 40.0–46.4 mm long (11.5–13.0 mm in carapace-length) and 11 females, 52.5–59.0 mm long (15.1–17.2 mm in carapace-length) were also dealt with.

Locality: Kumanonada: Heta, Sizuoka Pref.: Tateyama, Tiba Pref. (August, 1928, S. S. Sôyô-Maru).

Note: The upper rostral spines are 5 or 6 in number irrespective of six and age, posterior 3 of which are always found laid down on carapace.

As regards proportional lengths of rostrum, sixth abdominal somite, telson, upper antennular flagellum, and last six pairs of thoracic appendages, to carapace, the present species shows some extent of variation as given in Table 21. In none of these items, however, this species is sexually dimorphic.

Table 21. Ratios, in length against carapace of rostrum (*A*), sixth abdominal segment (*B*), telson (*C*), upper antennular flagellum (*D*), third maxilliped (*E*), and pereiopods from first to fifth (F_1–F_5).

	A	B	C	D	E
♂	1.8–2.2	0.46–0.53	0.46–0.53	1.32–1.61	1.50–1.61
♀	1.9–2.3	0.45–0.49	0.45–0.51	1.37–1.59	1.46–1.62
	F_1	F_2	F_3	F_4	F_5
♂	1.00–1.12	1.46–1.56	2.07–2.13	1.52–1.65	1.92–2.07
♀	1.02–1.10	1.41–1.63	1.86–2.15	1.32–1.64	1.91–2.07

Remarkably enough, the relative length of the fifth pereiopod against the carapace is decidedly smaller than those of all other Solenocerae dealt with, regardless of sex, as graphically indicated in Fig. 100, *F*.

The present species is most closely related to *Sol. distincta* DE HAAN

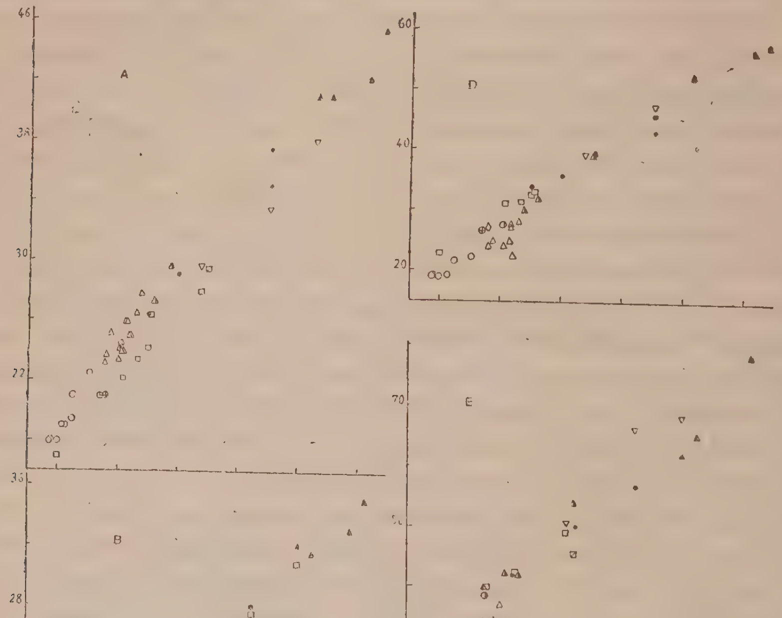

Fig. 100. Showing dimensions (in mm) of third maxilliped (*A*), first (*B*), second (*C*), third (*D*), fourth (*E*), and fifth (*F*) pereiopods in relation to carapacial length (in mm). ●, male of *Solenocera prominentis*; ▲, female of *S. prominentis*; ◑, male of *S. depressa*; ◭, female of *S. depressa*; ⊕, male of *S. faxoni*; ◇, female of *S. faxoni*; □, male of *S. subnuda*; ▽, female of *S. subnuda*; ○, male of *S. brevipes*; △, female of *S. brevipes*; ⧅, female of *S. alticarinata.*

(De Haan, op. cit., and De Man, op. cit., pp. 51–52) in possession of the following characters:—(1) pterygostomian spine present, (2) rostrum rather short, armed with 6 teeth on upper border, anterior two of which laid down on rostrum proper, (3) antennular peduncle almost reaches to apex of antennal scale, and (4) thoracic limbs shorter. For differentiation of these two forms, however, it may be mentioned that the present species has (1) the groove running along postrostral carina absent altogether: (3) fifth pereiopods reach beyond tip of first pereiopods by about one-third of propodus and entire dactylus (not beyond tip of the cheliped in *Sol. distincta*). Besides these, the present species seems to be greatly different from Balss's *Sol. distincta* (1914, pp. 5–6, Fig. 1) in general especially apical feature of petasma.

Again, *Sol. koelbeli* De Man, which has been identified with *Sol. distincta* De Haan by Balss (*loc. cit.*), is also very near to the present species, especially in the annexed characters: (1) antennular peduncle reaches to apex of antennal scale, and (2) pereiopods of "5th pair reach only with their dactyli beyond the antennal scale" (De Man, *op. cit.*, p. 51). However in De Man's *Sol. koelbeli* (*loc. cit.*), "the cervical groove is not interrupted by the post-rostral carina" and "the external maxilliped extend only to apex of antennal scales," instead of being in *Sol. brevipes*, that the cervical groove is found interrupted by the carina, and the third maxillipeds surmount the distal ends of the antennal scales by about entire dactylus.

On the other hand, from *Sol. prominentis*, *Sol. alticarinata*, *Sol. depressa* and *Sol. faxoni*, the present species is easily separable basing on the following features: (1) a well-developed pterygostomian spine present; (2) both segments of mandibular palp subequal in length, in all other species dealt with herein the distal joint is shorter than the other; (3) relative length of the fifth pereiopod as referred to carapace distinctly smaller (Fig. 100, *F*); (4) ventral lobule of median lobe of petasma surmounts the distal ends of lateal lobe and dorsal lobule of median lobe by the strikingly developed oval projection; (5) the last thoracic sternite has a rather prominent median upheaval at about middle.

Solenocera pectinulata sp. nov.

(Figs. 8, *S*; 27, *A* and *B*; 66, *K* and *L*; 72, *N* and *T*; 80, *B*; 101; 102, *A*–*C*).

Rostrum rather short, horizontal, reaching about two-fifths of first antennular peduncle, twice as long as wide measured at base exclusive of spine, two-ninths the length of carapace; upper border almost straight, armed with 7 teeth, posterior 3 of which located on carapace, fifth tooth a little behind postorbital margin, the last one at about a fourth of carapace and twice as far distant from penult as penult from antepenult;

lower border convex, devoid of teeth. Carapace has postorbital, hepatic and antennal spines in addition to branchiostegal one which is flat closely resembling that of *Sol. faxoni*. Postrostral carina extends a little in front of middle of carapace. Cervical groove deeply cut, slopes up almost reaching to end of postrostral carina. Hepatic well defined, running horizontally backward below upper end of cervical groove. Supra-orbital angle minutely notched, but not spiniform at all. Abdomen has a mid-dorsal carina commencing from two-thirds of third somite and ending in a sharp spinule at postmedian edge of six somite. Sixth pleonic somite one and half times as long as wide, a little less than half the length of carapace. Telson very similar to that of *Sol. brevipes*.

Eyes rather large, somewhat exceeded by distal rim of first segment of antennular stalk. Stylocerite stretching about halfway of the joint, on which it lies. Antennular flagella different in length and size; upper ramus longer and narrower than the other, not channeled, about 0.24 mm broad in ninth article from tip, filamentous in apical five articles, about 1.3 times as long as carapace (Fig. 102, *A*); lower one made up of 55 articles, ca. 0.33 mm wide in seventh article from apex, ends rather abruptly with a very small apical article (Fig. 102, *B*). Antennal scale surpassing far end of antennular peduncle by its about one-fifth with a stout disto-lateral spine extending as far as apex of lamella. Carpocerite attains middle of scaphocerite.

Mandible: molar process almost flat and ovoid on masticatory surface, produced to a blunt point at postero-median angle; inciser one has a minute notch on cutting edge; palp reaches third segment of antennal peduncle, resembles that of *Sol. alticarinata*, first joint as long as wide measured at the broadest region, second one 1.5 times as long as wide, and also 1.5 times as long as the first segment (Fig. 8, *S*). Endopodite of maxillula unsegmented, rounded at apex, bearing a triangular expansion with 4 long setae at about middle of anterior margin and a similar one near base of posterior margin. First maxilliped is of Type-H_{2a}; inner distal endite rather narrowly rounded at apex, thrice as long as wide endopodite 5-segmented; ratios in length to the last joint; first 2, second 0.4, third 0.6, fourth 1.2; exopodite rather narrow, its distal fifth tapering to a point. Second one pediform, proportions in length to dactylus, merus 3, carpus 0.9, propodus 0.8; merus about 3.5 times as long as wide; dactylus narrowly rounded at apex, twice as long as wide. Third one stretches beyond distal end of scaphocerite by half of propodus and entire dactylus; relative length referred to the last segment: ischium 1.5, merus 1, carpus 1.2, propodus 1.1; meropodite about 6 times as long as wide.

First pereiopod reaches far end of second segment of antennular peduncle, furnished with a basial and ischial spines, ratios in length to movable finger: ischium 1.4, merus 2.1, carpus 1.9, palm 0.5; merus ca. 8 times as long as wide, somewhat thinner than ischiopodite but a little thicker than carpopodite. Second one surmounts beyond far end of antennal scale by about half of movable finger; proportions in length to dactylus: ischium 1.2, merus 2.2, carpus 3.5, and palm 0.5; merus ca. 7 times as long as wide. Third one broken off from about middle of carpus; merus ca. 10 times as long as wide, twice the length of ischium. Fourth surpasses distal tip of antennal scale by entire dactylus, much slenderer than third one, proportion in length to the last segment: ischium 1.1, merus 1.8, carpus 2.5, propodus 1.2; meropodite 10 times as long as wide. Fifth one mutilated distad from about middle of carpus, merus about twice as long as ischium.

Second abdominal appendage of male has a triangular prominence on outer surface of stalk as in *Sol. prominentis* and others. Appendix masculina: projection of proximal piece rather short, pointed spur-like, directed sidewise. A tuft of long wavy hairs present near anterior base of the projection. Distal two scales bill-like, different in size; inner one of which fringed with thickly set long hairs along anterior outer and apical margins, larger than the other which is hidden behind inner one and carries short hairs along distal edge (Fig. 66, *K* and *L*).

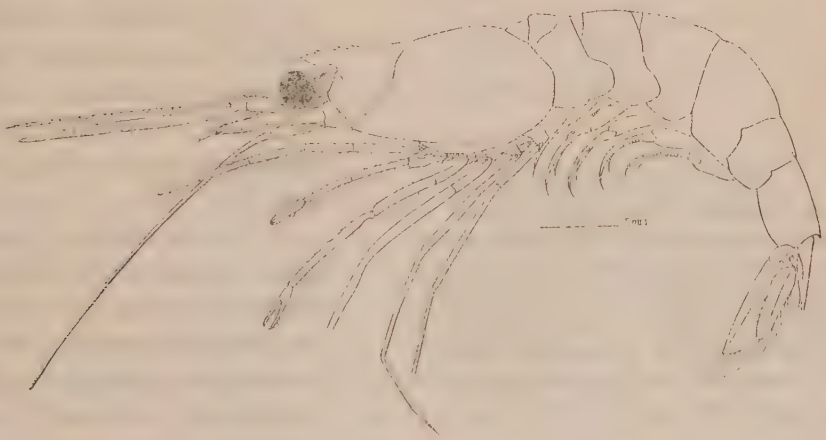

Fig. 101. *Solenocera pectinulata*, sp. nov., male.

Petasma similar to that of *Sol. faxoni*, but differs from it in the following respects; bristles beset on distal margins of both median and lateral lobes much larger; number of the bristles 21 in median lobe, 7–9 and 20 in dorsal and ventral lobules of lateral lobe respectively; process–*a* reaches about seven-eighths of ventral lobule of lateral lobe, serrated with several setae along apical margin; process–*b* located on dorsal surface somewhat anterior to process–*a*, foliaceous, twice as long as wide, directed medially, armed along inner edge with about 12 setae pointing inwards, intermediate 4 or 5 of which are much larger than others (Fig. 27, *A* and *B*).

Cardiac plate has about 20 spinules (Fig. 80, *B*). Zygocardiac ossicle armed on anterior edge of inner surface with 3 large sharply pointed teeth, the upper most one of which is followed by a longitudinal row consisting of rather sparsely set 6 small teeth (Fig. 80, *B*). Urocardiac strikingly expanded in anterior portion with trapezoidal outline (Fig. 72, *N*). Prepyloric ossicle invertedly subpentagonal in upper aspect, tapering in posterior half, provided with 10 acuminate spines (Fig. 72, *N* and *T*).

Type specimen: male about 38 mm long, 10 mm in carapace-length, mutilated, missing tip of telson, and distal two segments of third and fifth pereiopods, collected by Mr. Genkiti Abe.

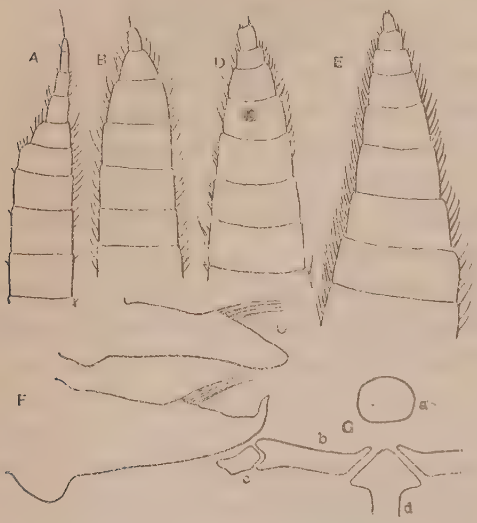

Fig. 102. *Solenocera pectinulata* (*A–C*) and *Solenocera subnuda* (*D–G*). *A* and *D*, distal portion of upper antennular flagellum, ×35; *B* and *E*, distal portion of lower antennular flagellum, ×35; *C* and *F*, endopodite of maxillula, ×25 in *C* and ×20 in *F*; *G*, cardiac (a), pterocardiac (b), prezygocardiac (c) and anterior about half of urocardiac (d) ossicles, ×35.

Type locality: Kumanonada (ca. 350 m in depth off Owase, Mie Pref).

Note: Peculiar to the present species in the genus *Solenocera:* fourth pereiopods reach beyond distal tips of antennal scales by at least entire dactyli; (2) petasma fringed with numerous prominent setae along distal about two-fifths of lateral margins, process–*a* and–*b* present, the former of which carries several sharply pointed setae on apical margin and the latter serrated with about 12 acute setae along inner margin; (3), appendix masculina provided with a tuft of long wavy hairs near anterior base of spur-like process of proximal piece.

The present species bears resemblance to *Solenocera pectinata* (Bate) (Bate and De Man, *op. cit.*). But it may be distinguished from the latter by the following respects (Table 22).

Table 22. Differences between *Sol. pectinulata* and *Sol. pectinata.*

Items	*Sol. pectinulata*	*Sol. pectinata*
(1) Vertical groove bridging hepatic and post-orbital spines	not recognizable	shallow, but distinct.
(2) Post-rostral carina	interrupts cervical groove at about middle of carapace	*interrupts cervical groove at about two-fifths of carapace
(3) Antennular peduncle	about 11/20 times as long as carapace	measuring two-thirds the length of carapace
(4) Petasma	distal third of lateral margin fringed with fine setae, of which those of proximal half much smaller than those of the other half in size	distal half of lateral margin fringed with large setae, of which those of proximal half not smaller than those of the other half in size

* as given in BATE's illustration.

Solenocera subnuda sp. nov.

(Figs. 8, *T*; 20, *O*; 27, *I-J*; 45, *C*; 66, *C* and *D*; 72, *M* and *S*; 80, *D*; 100; 102; *D-G*; 103).

Rostrum lanceolate, somewhat (ca. 20°) ascending, provided with a well-defined lateral carina sloping up to tip from post orbital margin, reaching a little behind distal end of first segment of antennular peduncle, about five-sevenths the length of carapace; upper border armed with 5 equidistant acute teeth which are directed antero-dorsally, foremost one of which located at about mid-way between tip and second tooth, and the hindmost one situated just above frontal margin of carapace; lower margin devoid of teeth. Postrostal carina rather defined, extending to posterior margin of carapace, more or less indented slightly anterior to its middle by cervical grooves, armed with 3 teeth closely similar to those of rostral ones, last one of which inserted at a fourth of carapace. Hepatic groove well-marked; anterior half with well-defined inferior rim, curved anteroventrally forming a broadly rounded loop a little behind frontal margin of carapace; posterior half horizontally extending backward slightly beyond upper end of cervical groove, not continued to branchio-cardiac groove. Branchio-cardiac rather marked with defined inferior edge as is the case with *Sol. alticarinata.* An ill-defined straight vertical groove arises in front of hepatic spine, runs nearly parallel to antero-lateral margin of carapace, and reaches behind antennal spine. Post-orbital and antennal spines present besides hepatic one, the former set below antepenult tooth of post-rostral carina, and somewhat larger than the latter. Supra-orbital angle minutely pointed. Pterygostomian angle broadly rounded.

Abdomen dorsally carinated behind first somite, but the carina of second somite faintly defined and that of sixth one ends in an acute spinule. Sixth pleonic somite 1.2 times as long as wide, two-fifths the length of carapace. Telson thrice as long as wide, without lateral spines, reaching to or beyond tip of inner upopods, somewhat less than half of carapace.

Eyes rather large, reniform, reaching a little behind distal end of first segment of antennular peduncle; basal peduncular segment has at dorsal distomedian angle a setose foliaceous thickened projection with pointed apex reaching to about middle of eye. Prosartema somewhat exceeds apex of eye. Stylocerite reaches to middle of first article of antennular peduncle. Antennular flagella subequal in length, 1.7 times as long as carapace; upper ramus abruptly tapers into a point in distal 10 articles, ca. 0.4 mm wide in seventh article from tip (Fig. 102, *D*), lower one rather abruptly pointed at apex, 0.5 mm broad in seventh article from distal end (Fig. 102, *E*). Basicerite has a small spine on distal outer margin. Scaphocerite surmounts far end of antennular peduncle by about its one-seventh, thrice as long as wide measured at base, with a disto-lateral spine extending as far as apex of lamella. Carpocerite subcylindrical, reaching more or less behind middle of scaphocerite.

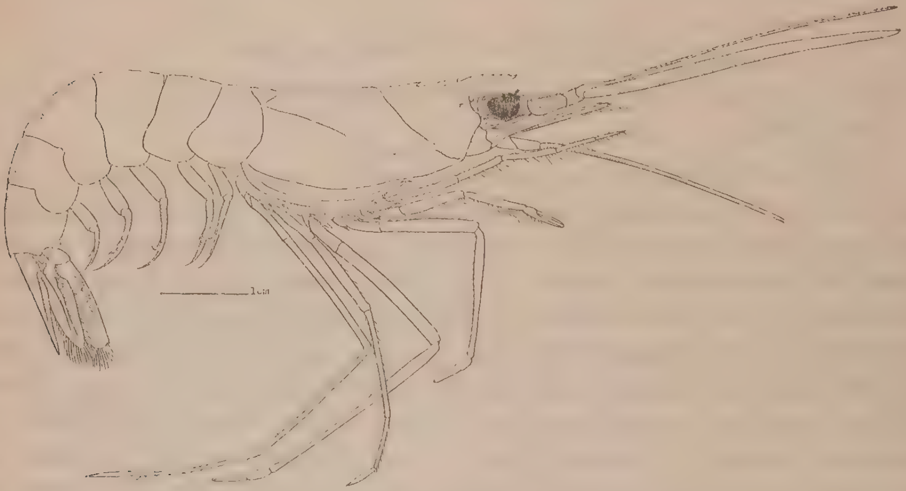

Fig. 103. *Solenocera subnuda*, sp. nov., female.

Mandible: molar process bears almost flat masticatory surface, rounded on anterior and sharply angulated on posterior masticatory edges; incisor provided with two small pointed teeth on cutting edge. Mandibular palp reaches distal inner end of fourth segment of antennal peduncle; first joint subtriangular in outline, about as long as wide measured in widest regin; second one gradually narrowed in distal two-thirds, twice as long as wide, 19 times the length of first segment (Fig. 8, *T*). Endopodite of maxillula unsegmented, tapers into a point, turns rightangularly forward in subterminal portion, furnished with several long bristles at about three-fifths of anterior border and a semicircular swelling at base of posterior one (Fig. 102, *F*). Maxilla is of Type–G_1. First maxilliped similar to that of other species of *Solenocera;* inner distal endite ca. 3 times as long as wide; endopodite slender, five-segmented, subequal in size except first joint, about seven times as long as wide in fourth joint, ratios in length to the last segment: first 1.4, second 0.3, third 0.5, fourth 1.5; exopodite narrow, nine times as long as broad measured at middle, with rounded basal and nearly straight lateral margins, but gradually narrowed into a point in distal third. Second maxilliped pediform, seven-jointed; proportions in length to dactylus: merus ca. 3, carpus 0.9, propodus 0.6; meropodite 3.6 times as long as wide, lamellar on inner side; dactylus twice as long as wide, with rounded apex. Third maxilliped exceeds tip of antennal scale by half of dactylus, 7 times as long as wide in merus, relative lengths as referred to dactylus: ischium 2.5, merus 1.5, carpus 1.9, propodus 1.3; exopodite reaching middle of ischiopodite.

First pereiopod stretching to far end of second article of antennular peduncle, somewhat thicker than third maxilliped, with carpus 8 times as long as wide, bearing both basial and ischial spines, and has rather long fine hairs along posterior rim, proportions in length to movable finger: ischium ca. 1, merus and carpus 2, palm 0.4; chela with nearly straight prehensile edges, pointed at tip, palm 1.6 times as long as wide. Second one reaches beyond apex of scaphocerite by entire chela, with a basial spine, 1.1 times as long as carapace, thicker than first one, 7.5 times as long as wide in merus, proportions in length to movable finger: ischium 1.1, merus 3.1, carpus 4.1, palm 0.5; chela resembles that of first cheliped. Third extends beyond antennal scale by somewhat less than half the length of carpus and entire chela, about 1.6 times as long as carapace, ratios in length to movable finger: ischium 1.1, merus 3.9, carpus 5.9, palm 0.66; ischium, merus and proximal about half of carpus subequal in size, about 11 times as long as broad in merus, but distal portion of carpus about a third the width of marus; chela similar to those of preceding limbs, thrice as long as wide in palm. Fourth one attains tip of antennal scale, 1.8 times the length of carapace, relative lengths against dactylus: ischium 1.5, merus 2.6, carpus 3.1, propodus 1.6; merus 8 times as long wide; dactylus spatulate, sharply pointed at tip. Fifth one the longest of all, exceeds distal end of antennular peduncle by terminal two segments, ratios in length to dactylus: ischium 1, merus 2.5, carpus 3, propodus 2.3. Exopodite of first pereiopod reaching distal end of ischium, and that of the following pairs succeedingly smaller.

Petasma resembles that of *Sol. faxoni;* dorsal lobule of median lobe more or less thickened, unarmed, and slightly curved ventrally at apex, somewhat surpassing distal margin of the other lobule of the lobe; ventral lobule of median lobe serrated with many minute setae along distal margins, and provided with two well-calcified pointed processes directed sidewise on lateral margin of subterminal portion, anterior one of which thinner and longer than the other one (Fig. 27, *J*); lateral lobe fringed along distal quarter of outer (or ventral) margin with numerous setae; process–*a* large, rounded, without setae, and recurved sidewise at apex, directed antero-medially; process–*b* absent.

Thelycum: An obtuse tubercle present directed postero-ventrally near postero-median base of each fourth pereiopod. The last thoracic sternite has two conical median processes, of which anterior one lying close to anterior edge, posterior one on sternite between fifth pereiopods and much larger than the other; and has an inconspicuous rather narrow transverse elevation which runs between the conical processes, and curved on either side rightangularly backward reaching posterior edge of the sternite (Fig. 45, *C*).

Appendix masculina similar to that of *Sol. depressa.* Proximal piece is provided on inner surface with a bar-shaped projection which is convex at apex and directed infero-laterally, besides a ridge-like elevation on anterior surface. Two distal bill-like scales different in size, rather narrowly rounded at apex, inner one is fringed with thickly set rather long hairs on anterior outer and with short ones on apical margins, about twice the length of the process found on inner surface of proximal piece; outer one smaller than the other and bears short hairs along distal margin only (Fig. 66, *C* and *D*).

Cardiac plate armed on inner surface with about 16 pointed spinules arranged in a longitudinal series (Fig. 80, *D*). Cardiac ossicle suboval in outline, the length about 1.2 times the width, more convex on anterior than on posterior margin. Pterocardiac ossicle bar-shaped, about four times as long as wide; antero-median angle produced antero-medially with pointed apex, but postero-median one broadly rounded; median edge straight, running parallel to antero-lateral margin of urocardiac; outer end bifurcate with anterior larger and posterior smaller rounded protuberances. Prezygocardiac ossicle minute, subrectangular in outline, about twice as long as wide, and one-third the length of pterocardiac ossicle. Urocardiac ossicle triangularly dilated in anterior end with bluntly pointed anterior and rather sharply pointed lateral apexes (Fig. 72, *M*). Zygocardiac ossicle furnished with two sharply pointed large conical teeth on anterior edge, and about 11 acute rather long teeth arranged in a longitudinal row laid down just above the upper large tooth (Fig. 80, *D*). Prepyloric has about 10 slender acute teeth on each postero-lateral edge (Fig. 72, *M* and *S*). The one tooth found near anterior end of inner lateral wall of pyloric chamber in all other ex-examined species of *Solenocera* is absent.

Described and figured from a male and a female, 69.6 mm and 69.0 mm long (21.0 mm and 21.5 mm in carapace-length) respectively, obtained from south coast of Borneo by Assistant Prof. Sôiti SAITÔ, on Dec. 29, 1932. Besides these, five males, 36.5–61.0 mm long (12.0–18.2 mm in carapace-length) and two females, 69 mm and 85 mm long (21 mm and 29 mm in carapace-length) secured from the same locality came under my examination.

Note: The spines inserted on dorsal border of rostral carina varies 8–10 in number (mostly 9), and posterior 3 or 4 (mostly 3) are found on carapace.

It is worth mentioning that the antennular flagella seem to get relatively shorter with advance of growth in both sexes, and the apparatus of male appears to be relatively longer than those of female: the flagella measure 2.16 times the length of carapace in a juvenile male, 12.0 mm in carapace-length, and 1.69 times the length of carapace in a female, 21.0 mm in carapace-length, whilst they are 1.70–1.84 times of carapace in five males, 16.3–21.5 mm in carapace-length and 1.32 times the length of carapace in a female 29.0 mm in length of carapace.

Relative dimensions of third maxilliped and first to fifth pereiopods, as referred to carapace, are 1.30–1.45 in male and 1.25–1.37 in female; 1.10–1.15 in male and 1.05-1.09 in female; 1.58–1.70 in male and 1.58–1.63 in female; 2.27–2.50 in male and 2.34–2.53 in female; 1.80–1.90 in male and 1.80–1.81 in female; and 2.63–2.93 in male and 2.41–2.66 in female respectively. The data given above show that no sexual difference is found to exist in such facts.

The stalks of first and second abdominal appendages of the present species are sexually dimorphic as in other species of *Solenocera.* In addition to these, the present species is sexually dimorphic in carpopodite of the second pereiopod, viz., the segment in question has much more thick set hairs along its posterior margin in male than in female.

The present species is closely allied to *Solenocera prominentis*, but easily separable from the latter by the following salient characters: (1) telson devoid of lateral spines; (2) antennular flagella are about 1.7 times of carapace; (3) petasma has a pair of small fleshy protuberances at apex, and two pairs of well-calcified processes on subterminal lateral margins of median lobe, the process–*a* with unarmed distal margin, and the process–*b* absent; (4) thelycum is provided with a small tubercle directed posteriorly near postero-median base of each fourth pereiopod, and two different sized median conical elevations on the last thoracic sternite; posterior edge of the ultimate thoracic sternite not markedly upheaved.

Moreover, the present species appears to be near to *Sol. crassicornis* (H. MILNE-EDWARDS) (1837, p. 418), especially in having no lateral armatures on telson. But it is separable as given in the following table (Table 23).

Table 23.

Items	Present species	*Sol. crassicornis*
(1) Rostrum	armed with 8-10	with 10-12
(2) Branchiostegal or pterygostomian spine	absent	present*
(3) Third pereiopod	exceeds distal end of antennular peduncle by the length of antennular peduncle plus about one-fourth the length of carapace	exceeds distal end of antennular peduncle by the length of antennular peduncle

* According to BOUVIER (1908, p. 90) and BURKENROAD (1934, pp. 71-72).

Subfamily PENAEINAE BURKENROAD (emend)

Penaeinae, BORRADAILE, 1907 (part), p. 470; BALSS, 1914 (part), p. 5; BURKENROAD, 1934 a, p. 72.

Peneinae, ALCOCK, 1901 (part), pp. 11-12; 1906 (part), p. 3; SCHMITT, 1926 (part), p. 317.

Rostrum well developed, armed with teeth above and below or above only. Hepatic spine present. Epigastric, pterygostomian, branchiostegal spines present or absent. Post-orbital, post-antennal, and suprahepatic ones absent. Cervical groove not reaching to dorsum of carapace. Abdomen, except telson, dorsally carinated posteriorly. Telson pointed at apex, with or without dorso-lateral spines.

Eye is of Types-C_2 or C_3. Prosartema present. Antennular flagella usually cylindrical, sometimes basally compressed, but always attached to apex of third peduncular segment. Mandibular palp two-jointed, distal segment broad, longer and wider than proximal one. Maxillulary palp segmented or unsegmented. Maxilla provided with medially two gnathobasic laciniae, each of which is distally bifid, proximal lobule of posterior gnathobasic lacinia sometimes vestigal or absent at all. All maxillipeds furnished with exopodite. First maxilliped with five-jointed palp, exopodite rounded or bluntly pointed on anterior border. Third maxilliped pediform, sometimes sexually dimorphic. Pereiopods usually typical, but last two ones sometimes very slender or filiform; chelipeds increase in length posteriorly in most cases, the first one, however, rarely much longer than other ones. Exopodite of first four pairs of pereiopods present without exception, but that of the rearmost one present or absent.

Endopodite of pleonic appendage usually well developed, that of second one sometimes deformed in male.

Petasma is of Types, M_1–M_4, M_6, M_7, and M_9–M_{11}. Thelycum belongs to Types, N_2, N_4, N_5, N_7, and N_8. Appendix masculina made up of proximal and distal pieces, the former without spur-like projection, and the latter single and lobate.

Pleuro-branchia of the last thoracic somite present or absent. Arthro-branchia of the hindmost thoracic somite usually absent, but rarely present, that of the penult somite one or two in number. Podobranchia present on second maxilliped only. Mastigo-branchia of third maxilliped and anterior three pereiopods present or absent, but that of the last two legs always absent.

Cardiac plate armed with many sparsely set spinules alined longitudinally. Ptero-cardiac bar-shaped or sigmoid in outline. Zygocardiac with many teeth variable in size and arrangement. Prepyloric armed along postero-lateral borders with many pointed teeth.

Note: The annexed ten genera were treated herewith, viz., *Miyadiella*, *Penaeus*, *Penaeopsis*, *Metapenaeus*, *Trachypenaeopsis*, *Atypopenaeus*, *Parapenaeus*, *Parapenaeopsis*, *Trachypenaeus*, and *Metapenaeopsis*. They exhibit, amongst others, the following distinguishing, although sometimes easily overlooked, characteristics:—Carapace is of types, A_1–A_3. Eye is typical in all other genera except *Miyadiella*, in which it is strikingly elongated. Stylocerite is always present. Parapenaeid spine present in *Parapenaeus*, *Penaeopsis*, and *Metapenaeopsis*, but absent in the rest. Antennular flagella are variable in length, often sexually dimorphic in configuration. Mandibular palp is of Type–E_3 as is the case with Eusicyoninae. Maxillula is cross-shaped, made up of three laciniae. Exopodite of first maxilliped five-segmented as in that of Aristaeinae and Solemocerinae. Second maxilliped seven-jointed, inverted J–shaped. Third maxilliped is unarmed with basial spine in all other genera exclusive of *Metapenaeopsis*, that of *Penaeus* usually undergoes remarkable modification with sex in distal two joints, viz., propodus has on disto-dorsal border a protuberance which is provided with a tuft of long hairs, and dactylus somewhat spoon-shaped and grooved longitudinally on dorsal surface for reception of the tuft in male, but typical in female. Anterior three pairs of thoracic limbs bear basial and ischial spines in all, but *Parapenaeopsis gracillima*, which has all the limbs in question unarmed. First pereiopod has a basial and an ischial spines in *Parapenaeus* and *Trachypenaeopsis*. Each of the first two pairs of pereiopods is furnished with a basial spine only in *Parapenaeopsis tenellus*, *P. sculptilis*, *P. hungerfordi*, *P. hardwickii*, *P. cultrirostris*, *Penaeus japonicus*, *P. latisulcatus*, and in female of *Parapenaeopsis cornutus*. First pereiopod bears a basial and an ischial spines and second leg a basial one in *Trachy-*

penaeus, *Metapenaeopsis*, and *Penaeus* (excluing *Penaeus japonicus* and *P. latisulcatus*). Each of the anterior three pairs of thoracic limbs is in possession of a basial spine in *Metapenaeus joyneri*, *M. lysianassa*, *M. tenuipes*, *Parapenaeopsis maxillipedo*, in male of *Parapenaeopsis cornutus*; the spines of third limb is strikingly developed having an apical hook in male of *M. joyneri*. A basial spine is present on first three pereiopods besides an ischial one on first limb in *Metapenaeus monoceros*, *M. intermedius*, *M. brevicornis*, *M. spinulatus* and *M. affinis*. Pereiopods from first to third have a basial spine and anterior two pereiopods an ischial one in *Miyadiella pedunculata* alone. A basial spine exists on second and third pereiopods and an ischial one on first two pairs of legs in *Atypopenaeus compressipes*. Exopodite is present on all legs in *Miyadiella*, *Penaeus* except *P. bubulus*, *Penaeopsis*, *Trachypenaeopsis*, *Atypopenaeus*, *Parapenaeopsis*, *Trachypenaeus*, *Parapenaeus*, *Metapenaeopsis*, but that of the last pereiopod is absent in *Metapenaeus* and *Penaeus bubulus*. Endopodite is well developed and typically formed in pleonic somites, but that of the second modified in male of some species of *Parapenaeopsis*.

Pleuro-branchia usually absent on the hindmost thoracic somite, but present in *Penaeus* only. Arthro-branchia absent on the last thoracic somite in all other genera dealt with except *Miyadiella*, in which it is present. Again arthro-branchia of penult thoracic somite is single in number in *Atypopenaeus*, *Parapenaeus*, *Penaeopsis*, *Trachypenaeus*, *Parapenaeopsis*, *Penaeus*, and *Metapenaeopsis lamellatus*. However two arthro-branchiae (anterior one of which is rudimentary) are present on the same thoracic somite in *Metapenaeopsis* except *M. lamellatus*, *Metapenaeus*, and *Trachypenaeopsis*. A podo-branchia exists on second maxilliped only. Mastigo-branchia of first two thoracic appendages is always present, and that of the last two ones is always absent, that of third maxilliped is absent in all other genera dealt with, but present in *Penaeus*, and that of first to third pereiopods is present or absent.

Key to the genera of the subfamilies Penaeinae

A_1 Petasma symmetrical; third maxilliped without basial spine; zygocardiac ossicle is of Types, $R_{1\text{-}3}$, and R_6

  B_1 Carapace without longitudinal sutres; appendix masculina is of Types, O_1, O_5 and O_7

    C_1 Eye strikingly elongated, with cornea as broad as stalk; petasmal endopodites without longitudinal folds, not united with each other (Type-M_1) ....**Miyadiella, gen. nov.**

    C_2 Eye typical, with cornea much wider than stalk; petasmal endopodite complicated, with well-developed longitudinal folds (Types, $M_{2\text{-}4, 9, 10}$)

      D_1 A pleurobranchia present on the last thoracic somite, a mastigo-branchia exists on third maxilliped; carapace with gastro-orbital carina; zygocardiac ossicle with many rather sparsely set teeth alined longitudinally (Type-R_1) ....**Penaeus.**

D_2 Pleurobranchia absent on the last thoracic somite; mastigobrachia absent on third maxilliped; carapace without gastro-orbital carina; zygocardiac ossicle with many teeth not arranged in a longitudinal row (Types, $R_{2,3,6}$)

E_1 Brachiostegal spine present; maxillulary palp unsegmented; petasma provided with a pair of large spiniform disto-lateral projections; pterocardiac ossicle S-shaped in outline, armed with a large pointed process on anterior margin ....**Penaeopsis.**

E_2 Branchiostegal spine absent; maxillulary palp two-segmented; petasma carries a pair of tubular disto-lateral projections; pterocardiac ossicle simply bar-shaped, without process on anterior border

F_1 Seventh thoracic somite furnished with a pleurobranchia; fifth pereiopods without exopodite ....**Metapenaeus.**

F_2 Seventh thoracic somite without pleurobranchia; fifth pereiopod bearing an exopodite

G_1 Telson armed with mobile and fixed dorso-lateral spines; second and third pereiopods without basial and ischial spines; zygocardiac ossicle furnished with well-developed many teeth arranged in two longitudinal rows ....**Trachypenaeopsis.**

G_2 Telson devoid of dorso-lateral spines; second pereiopod has a basial and an ischial spines, and the third with a basial one; zygocardiac ossicle has many irregulary set accessory teeth besides three large pointed teeth lying on anterior edge ....**Atypopenaeus.**

B_2 Carapace with longitudinal sutures, appendix masculina is of Types, $O_{2,4,6,8}$.

H_1 First leg without ischial spine; appendix masculina belongs to Type-O_6 or Type-O_8; longitudinal suture of carapace attains about the middle ....**Parapenaeopsis.**

H_2 First leg has an ischial spine; appendix masculina is of Type-O_2 or Type-O_4; longitudinal suture of carapace reaching above hepatic spine or almost reaching to posterior margin of carapace

I_1 Longitudinal suture of carapace extending above hepatic spine; telson without fixed dorso-lateral spine; second leg with a basial spine; sixth thoracic somite having a mastigobranchia, seventh thoracic somite without pleurobranchia; exopodite of all pereiopods not rudimentary; appendix masculina with distal piece quadrate in outline, plate-like, but considerably thickened; petero-cardiac ossicle simply bar-shaped, without acute process on anterior border ....**Trachypenaeus.**

I_2 Longitudinal suture of carapace nearly reaching to posterior margin of carapace; telson provided with a pair of fixed dorso-lateral spines; second leg without basial spine; sixth thoracic somite has no mastigo-branchia, the seventh with a pleuro-branchia; exopodite of all pereiopods vestigial; distal piece of appendix masculina thickened, fist-like in feature; pterocardiac ossicle sigmoid in outline, armed with a prominent acute process on anterior edge ....**Parapenaeus.**

A_2 Petasma asymmetrical; third maxilliped provided with a basial spine; telson with a pair of immovable dorso-lateral spines besides movable ones; pterocardiac ossicle bar-shaped; zygocardiac one is of Type-R_5 ....**Metapenaeopsis.**

Genus *Miyadiella* gen. nov.

Rostrum well developed, with teeth. Hepatic spine present. Telson tapering to a point. Eye very slender reaching beyond distal end of first segment of antennular peduncle. Antennular flagella cylindrical, somewhat shorter than carapace. Antennal flagella not much longer than antennular ones. Dactyli of last two pereiopods simply pointed. Exopodite present on all thoracic appendage. Appendix masculina is of Type–O_1. Petasma belongs to Type–M_1. Cardiac plate has many spinules arranged in a longitudinal series. Pterocardiac ossicle simply bar-shaped. Zygocardiac is of Type–R_3. Prepyloric armed with teeth along each postero-lateral edge.

Genotype: *Miyadiella pedunculata* sp. nov.

The present new genus bears resemblance to *Penaeus* in many respects already set forth elsewhere in this paper. However, it may be easily separated from the latter as well as from all other genera of Penaeidae by the diagnostic features of eyes as given above.

Miyadiella pedunculata sp. nov.

(Figs. 7, *N*; 23, *G* and *H*; 58, *O*; 74, *C* and *I*; 79, *E*; 104; 105)

Body small, glabrous. Rostrum horizontal, sharply pointed at apex, with low lateral carina arising from post-orbital margin, about 2.5 times as long as wide measured in basal lateral surface, reaching middle of corneal peduncle or first segment of antennular peduncle; upper border nearly straight, serrated with 6 teeth which become gradually smaller in size toward tip; while lower one slightly convex, devoid of teeth. Carapace is of Type–A_{1a}. Abdomen dorsally carinated backward to middle of fourth segment; pleura from first to fifth segments rounded on both anterior and posterior margins but nearly straight or slightly convex on lower margin except that of first segment, in which it is rather markedly produced downwards with broadly rounded apex; sixth segment one and half times as long as wide, provided with a sharp spinule at posterior end of mid-dorsal carina and with a similar one each lower edge slightly in front of postero-inferior angle, a little less than half the length of carapace. Telson pen-shaped with bluntly pointed apex, devoid of lateral spines, reaching tip of inner uropod, 2.5 times as long as wide measured at base, and about half the length of carapace, has a shallow dorsomedian groove and a narrow lamellar lateral expansion with long hairs along outer edge in posterior quarter (Fig. 105, *A* and *B*). The last thoracic sternite has a sharply pointed spine directed antero-ventrally between fifth pereiopods.

Eyes very slender, attains somewhat behind distal margin of second antennular segment. Antennular peduncle three-segmented; basal segment depressed, subrectangular in outline, has a spinule at disto-lateral angle, thrice as long as wide, about one-third the length of carapace, furnished with a stylocerite reaching middle of this segment and a prosartema which is rounded at apex and extending as far as stylocerite; intermediate one rectangular in upper aspect, three times as long as wide, about four-fifths the length of basal article; the last one somewhat more than one-third the length of second joint, slightly narrower than the joint. Antennular flagella subequal in length, cylindrical, somewhat hairly, about 0.7 times the length of carpace. Basicerite without spinule on anterior outer edge. Scaphocerite reaches to far end of antennular peduncle, slightly tapers into a rounded apex, four times as long as wide measured at the broadest region, has a distolateral spine which is greatly exceeded by apex of lamella. Carpocerite subcylindrical, attains distal edge of basal peduncular segment. Antennal flagella more or less longer than those of antennula, ca. 0.8 times the length of carapace.

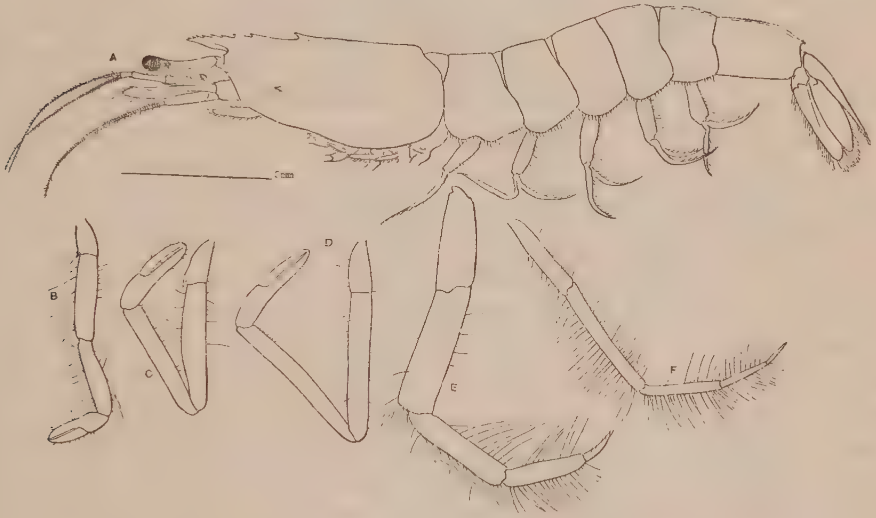

Fig. 104. *Miyadiella pedunculata* sp. nov. *A*, lateral aspect of a male, without third maxilliped and all pereiopods, ×4; *B–E*, first—fourth pereiopods, ×10; *F*, fifth one, ×7.

Mandibular palp foliaceous, two-jointed; basal segment invertedly triangular in outline, as long as wide; distal one lunate in outline with nearly straight inner margin and narrowly rounded apex, a little less than twice as long as wide measured at the widest region, 2.5 times the length of basal segment (Fig. 7, *N*). Maxillula is of Type–F_{1b}; proximal endite thumb-like in outline tipped with thickly set setae; distal endite somewhat larger than proximal one, with setae at apex as in the other endite; endopodite narrowly rounded at apex, expanded on both sides with marked convex apical border bearing sparsely set hairs, armed with an acute spine at middle of anterior border (Fig. 105, *F*). Maxil-

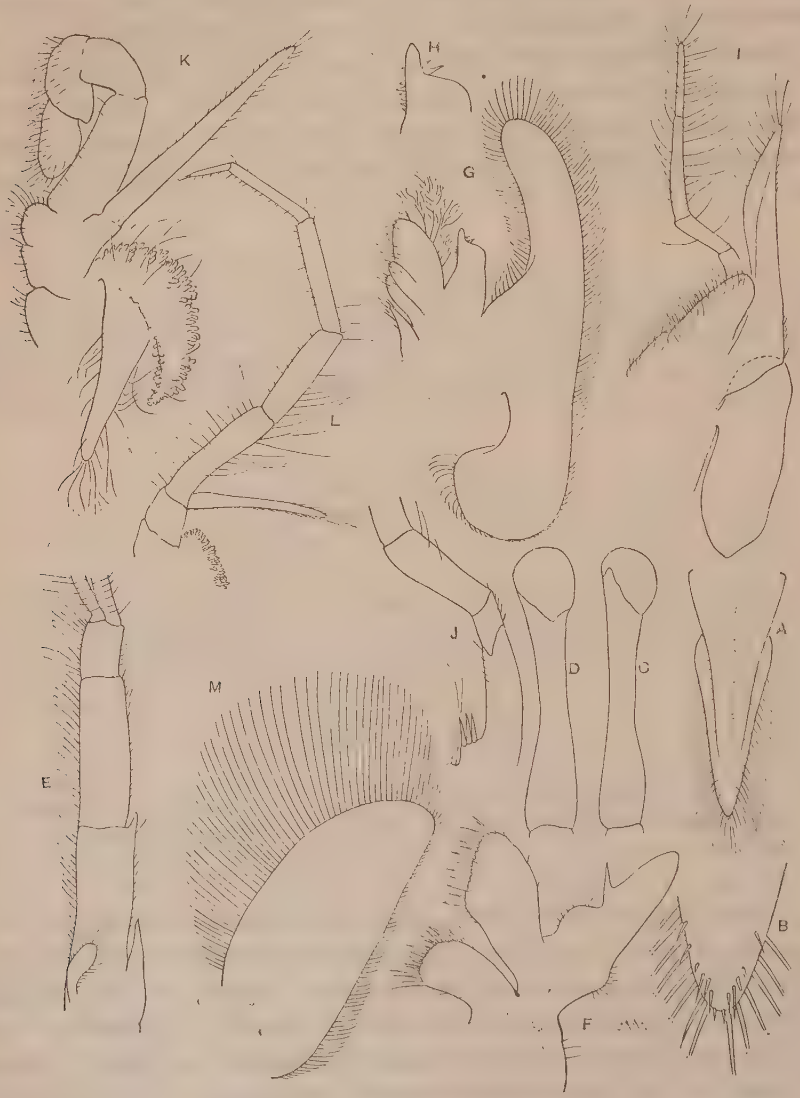

Fig. 105. *Miyadiella pedunculata*, sp. nov. *A*, upper aspect of telson, ×ca. 10; *B*, tip of telson, ×50; *C*, dorsal view of eye, ×20; *D*, lateral view of eye, ×20; *E*, upper aspect of antennular peduncle, ×20; *F*, maxillula, ×35; *G*, maxilla, ×35; *H*, tip of endopodite of maxilla; *I*, first maxilliped, ×35; *J*, basal portion of endopodite of first maxilliped, ×50; *K*, second maxilliped with branchiae, ×25; *L*, third maxilliped with a part of branchia, ×20; *M*, outer uropod, ×15.

la is of Type–G_1; endopodite bearing a pointed protuberance at distal inner angle, furnished with a thicket of short setae on inner surface near base of the apical protuberance and two or three setae opposite the thicket; exopodite ear-shaped, sparsely fringed with hairs along entire border (Fig. 105, *G* and *H*). First maxilliped well-developed; endopodite slender, five-segmented, proportions in length to the last segment: first 0.9, second 0.3, third 0.8, fourth 1.4; exopodite rather narrow, pointed at apex, not reaching to tip of endopodite (Fig. 105, *I* and *J*). Second one segmented into seven; meropodite subrectangular in outline, thrice as long as wide; carpopodite fig-shaped, 1.2 times as long as wide measured at the widest region, about half the length of merus, directed inwards at right angles; propodite similar to carpus in configuration, 1.8 times the length of meropodite, pointing backward; dactylus as large as carpus with rounded apex, directed rearward; exopodite measures twice the length of meropodite, tapers into bluntly pointed tip (Fig. 105, *K*). Third one pediform, extending a little beyond distal end of antennular peduncle, ratios in length to dactylus: basis 1, ischium 3, merus 2.3, carpus 2.6, propodus 2; ischium and merus subequal in size, ca. 3.5 times as long as wide, but distal three joints get successively smaller, ca. two-fifths the width of merus in propodus; exopodite reaching somewhat beyond far end of ischiopodite (Fig. 105, *L*).

First pereiopod attains tip of rostrum has an ischial spine, ratios in length to movable finger: ischium 1, merus 2.1, carpus 1.9, palm 0.6; merus four times as long as wide (Fig. 104, *B*). Second one reaching slightly beyond far end of antennular peduncle, armed with an ischial spine, ratios in length to movable finger: ischium 0.9, merus and carpus 2.2, palm 0.7; carpus a little slenderer than merus which measures about 5.5 times as long as wide (Fig. 104, *C*). Third one ca. 1.8 times the length of first pereiopod; meropodite thrice the ischium in length, a little shorter and thicker than propodus which is 9 times as long as wide; movable finger two-fifths the length of merus, about 1.2 times as long as palm, with unarmed straight cutting edge and pointed tip (Fig. 104, *D*). Fourth one slightly longer, but much thicker than third, proportions in length to dactylus: ischium and carpus 3, merus 3.4, propodus 2.2; ischium and merus similar in size, ca, 3.5 times as long as wide in merus which is about 1.6 times the width of the same joint of third pereiopod; distal four joints become gradually smaller and shorter, 4 times as long as wide in propodus (Fig. 104, *E*). Fifth one surpassing frontal margin of carapace by dactylus, by ca. 18% longer and ca. 60% thicker than fourth one, relative length as referred to dactylus: ischium 3, merus 4, carpus 2.6, propodus 1.8; merus about 8.5 times as long as wide (Fig. 104, *F*).

Appendix masculina spatulate in shape, with rounded apex (Fig. 58, *O*).

Petasma is of Type–M_1. Each lobe about 5 times as long as wide, with two apical lobules which are rounded at apex (Fig. 23, *G* and *H*).

Outer uropods longer than the other, lunate in outline with nearly straight outer and convex inner margins, fringed along entire margin with hairs, of which those of inner margin are very long, without spine at postero-lateral angle (Fig. 105, *M*).

Cardiac plate with 14–16 spinules (Fig. 79, *E*). Cardiac ossicle subquardrate in outline. Pterocardiac simply bar-shaped. Zygocardiac is of Type–R_3 (Fig. 79, *E*). Urocardiac with bluntly (ca. 120°) pointed anterior extremity, triangularly produced sidewise on each anterior subterminal lateral edge (Fig. 74, *C*). Prepyloric ends in a large bluntly pointed median tooth, armed on each postero-lateral rim with about 7 acuminate teeth which get successively larger in size posteriorly, much smaller than median tooth (Fig. 74 *C* and *I*).

Type specimen: A male, 19 mm long (6 mm in carapace-length) obtained from Osaka-wan.

Paratype: A male, 20 mm long (6.3 mm in length of carapace), taken from Nanao-wan. Both specimens were secured by Dr. D. MIYADI, during his surveys of benthic communities of these waters.

Note: The number of rostral spines of the paratype is 7 inclusive of epigastric spine, instead of 9, posterior 3 of which are, however, placed on carapace as is the case with the type specimen.

Genus *Penaeus* FABRICIUS (emend)

Penaeus, BATE, 1888, p. 229; RATHBUN, 1902 (for 1900), p. 100; DE MAN, 1911, p. 95; BALSS, 1914, p. 13; BURKENROAD, 1934, p. 74; VILLALUZ and ARRIOLA, 1938, p. 37.

Peneus, ALCOCK, 1901, p. 14 (pars); 1906, p. 7; SCHMITT, 1921, p. 31; BLANCO, 1937, p. 220.

Shell glabrous. Rostrum moderate, toothed above and below. Carapace with grooves and carinae. Antennul and hepatic spine present. Telson tapering into a point. Antennular peduncle has prosartema and stylocerite. Antennular flagella shorter than carapace. Mandibular palp foliaceous, two-segmented. Endopodite of maxillula and first maxilliped jointed. Appendix masculina has a distal scale. Exopodite present on all thoracic appendages anterior to fifth pereiopod, but that of the last limb is seldom lacking. Petasma symmetrical, spout-like, its cross-section being of Type–*B*.

Branchial arrangement (Table 6, *E*):—A pleuro-branchia on each thoracic somite backward to second one. An arthro-branchia on first and seventh thoracic somite, and two ones on somites from second to sixth. A podobranchia on second somite only. A mastigobranchia present on each of the anterior six somites.

Pterocardiac ossicle simply bar-shaped. Zygocardiac one armed on inner surface with many (usually conical) teeth arranged in a longitudinal row.

Note: The following 14 species are dealt with in this genus, viz., *P. japonicus* BATE, *P. latisulcatus* KISHINOUYE, *P. longistylus* KUBO, *P. teraoi* sp. nov., *P. brebirostris* KINGSLEY, *P. monodon* FABRICIUS, *P. bubulus* sp. nov., *P. esculentus* HASWELL, *P. stylirostris* STIMPSON, *P. vannamei* BOONE, *P. orientalis* KISHINOUYE, *P. penicillatus* ALCOCK, *P. merguiensis* DE MAN, and *P. indicus* H. MILNE-EDWARDS, of these 11 are Indo-Pacific inhabitants and 3 are endemic to Pacific coast of America. They have much morphological resemblance to each other, bearing many characteristics unshared by prawns of other genera. However, they may be divided into three subdivisions, viz., *P. japonicus*, *P. monodon*, and *P. orientalis*-groups, taking the annexed items into consideration: the condition of the adrostral groove and presence or absence of the hepatic and gastro-frontal carinae. The first group is represented by *P. japonicus*, *P. latisulcatus*, *P. longistylus*, *P. teraoi* and *P. brevirostris*. The adrostral groove is clearly cut and nearly extends to posterior margin of carapace, and welldefined gastro-frontal and hepatic carinae are common to this group, anterior two of which are not shared by other groups. The second group comprises *P. monodon*, *P. bubulus*, *P. esculentus*, *P. stylirostris* and *P. vannamei*. This group is characterized as follows: the adrostral groove rather deep, reaching just below the last tooth of the postrostal series or somewhat beyond it; the hepatic carina well-marked as is the case with the first group, but the gastro-frontal one absent at all. The third group involves *P. orientalis*, *P. penicillatus*, *P. merguiensis* and *P. indicus*. It is peculiar to these species that adrostral groove is shallow, decreasing in depth backward and fades out near the hindmost rostal tooth and both hepatic and gastro-frontal carinae entirely absent.

Summarizing the facts given above, it may be easily understood that the *P. japonicus*-group is the most specialized, and the *P. monodon*-group is intermediate between other two groups. It is very interesting to find that *Penaeus bubulus* has an appearance transitional from *P. japonicus*-form to *P. orientalis*-form at least in the conditions of the median, adrostral grooves and the hepatic and adrostral carinae.

BURKENROAD (1934, pp. 74–75) divided the animals of the present genus into two subgroups basing on the feature of adrostral carina and presence or absence of the gastro-frontal crest. However, it goes without saying that his classification is rather artificial as compared with mine.

Remarkably enough, the branchial formula given by ALCOCK (1906, p. 7) for the present genus holds good for all the species dealt with herein. But that given by BATE (1888 p. 227) stands at variance in such features as the pleurobranchia of the second thoracic segment is absent in our specimens, and the podobranchia of the second thoracic one is overlooked by him.

In regard to the endopodite of the maxillula, ALCOCK (*loc. cit.* p. 7) mentions "distinctly three-jointed". However, it is found two segmented at least in *P. indicus* and its congener examined, although mostly three-segmented in this genus. Thus the generic character should be emended as given above.

The endopodite of the first maxilliped is described by RATHBUN (1902, p. 100) as composed of four segments. But the appendage is found five-segmented in all the species of the genus *Penaeus* lying before the writer.

Key to the Species of *Penaeus*

A_1 Adrostral groove deep, nearly reaching to posterior margin of carapace; hepatic carin well-defined; gastro-frontal carina markedly defined ....**P. japonicus-group**

  B_1 Telson armed with three pairs of lateral spines; gastro-frontal groove has a loo

    C_1 Postrostral carina with clearly cut median groove; adrostral groove no markedly narrowed posteriorly from middle of carapace

      D_1 Stylocerite not extending to distal margin of basal segment of antennula peduncle; median groove of postrostral carina somewhat more than ha of the length of carapace; first pereiopod without ischial spine; thir pleonic somite not provided with a red circular pattern on each latera plate

        E_1 Rostrum armed with 8-10 teeth above and 1-2 ones below; adrostra groove a little narrower than postrostral carina; median lobes o petasma have at apex well-developed thickened protuberances whic entirely overhang distal margin of lateral lobes; seminal receptacl cylindrical with opening forward; anterior piece of thelycum rounde at apex ....*Penaeus japonicus* BAT

        E_2 Rostrum carries 9-12 teeth above, 1 tooth below; adrostral groove a wide as postrostral carina; median lobes of petasma have at ap rather developed thin protuberances which overhang upper about ha of distal margin of lateral lobe; seminal receptacle subrectangular outline, wider than long, made up of two lateral lobes; anterior pie of thelycum bifurcate at apex.

.........*Penaeus latisulcatus* KISHINOUY

      D_2 Rostrum with 12 spines above, a spine below; stylocerite nearly reachir far end of basal segment of antennular peduncle; median groove lyi on postrostral carina much less than half of the length of carapace; fi cheliped has an ischial spine; third pleonic somite provided with a rath large red pattern on each lateral plate; median lobes of petasma round at apex, extending as far as distal margin of lateral lobe; seminal ceptacle inverted dome-shaped in outline, composed of two lateral lob meeting along median line; anterior piece of thelycum somewhat elongat and rather bluntly pointed at apex ....*Penaeus longistylus* KUB

    C_2 Rostrum has 9-10 spines above, 1-2 ones below; postrostral carina witho median groove; adrostral groove becomes markedly narrower posterior to mid-way of carapace; median lobes of petasma rounded at apex, extending as far as distal margin of lateral lobe; seminal receptacle subrectangular in outline, longer than wide, made up of two lateral lobes meeting median line; anterior piece of thelycum bears a lanceolate apical process which is directed forward ....*Penaeus teraoi* sp. nov.

B_2 Rostrum furnished with 9 teeth on upper rim, and 2 on lower edge; telson devoid of lateral spines; gastro-frontal groove has no loop; median groove of postrostral carina ill-defined; adrostral groove becomes narrower backward to mid-way of carapace; each median lobe of petasma pointed at apex, overlapping distal margin of lateral lobe; each lateral lobe with minute auricular appendage on subterminal outer surface; seminal receptacle circular in outline, but slightly longer than wide, made up of two lateral lobes meeting along median line ....*Penaeus brevirostris* KINGSLEY.

A_2 Adrostral groove rather deep, extending just below epigastric tooth or somewhat beyond it; hepatic carina well-defined; gastro-frontal one absent at all ....**P. monodon-group.**

F_1 Third maxilliped greatly differs with sex; propodus has a tuft of hairs at distal upper end, dactylus deeply channeled on upper surface in male; lateral lobe of petasma has well-calcified thickened ventral margin which semicircularly curves upward in terminal portion; thelycum provided with a seminal receptacle consisting of two lateral lobes which meet along median line; appendix masculina less than twice as long as wide.

G_1 Postrostral carina bears well-marked median groove; cardiac plate armed with 20–23 spinules arranged in a longitudinal row

H_1 Rostrum armed with 6–8 teeth above, 2–4 ones below; adrostral carina sharp, reaching somewhat beyond epigastric spine; hepatic carina considerably (ca. 20°) inclined antero-ventrally; gastro-orbital carina occupies about posterior two-thirds of distance between postocular margin of carapace and hepatic spine; antennular flagella much shorter than peduncle; third leg stretches somewhat beyond middle of scaphocerite; distal piece of appendix masculina 1.2 times as long as wide ....*Penacus monodon* FABRICIUS.

H_2 Rostrum has 7–8 teeth above, 2–3 ones below; adrostral carina blunt, extending below epigastric spine; hepatic carina horizontally straight; gastro-orbital carina occupies posterior half of distance between postocular edge of carapace and hepatic spine; antennular flagella somewhat longer than the peduncle; third leg reaches beyond apex of antennual scale, at least attains tip of the scale; distal piece of appendix masculina about twice as long as wide ....*Penaeus bubulus* sp. nov.

G_2 Median groove absent on postrostral carina, cardiac plate armed with 17 spinules; rostrum with 5–7 teeth on upper border, 2–4 one on lower one; heprtic carina horizontally straight; gastro-orbital carina occupying posterior about two-thirds of distance between post-orbital rim of carapace and hepatic spine; antennular flagella as long as the peduncle; third pereiopod attains two-thirds of scaphocerite; distal piece of appendix masculina 1.2 times as long as wide ....*Penaeus esculentus* HASWELL.

F_2 Third maxilliped typical in both sexes; ventral margin of lateral lobe of petasma ill-calcified, not thickened, gently curves upward in distal about one third; thelycum has no seminal receptacle; distal piece of appendix masculina more than twice as long as wide

I_1 Rostrum armed with 7–8 teeth on dorsal border, 2–4 ones on ventral one; adrostral carina extends somewhat beyond epigastric tooth; longer antennular flagellum a little longer than the peduncle; fifth pereiopod of female has a strikingly developed coxal plate; median lobe of petasma bluntly pointed at apex, reaching slightly beyond tip of lateral lobe; the last thoracic sternite provided with a prominent pyramidal upheaval; distal piece of appendix masculina thrice as long as wide; zygocardiac ossicle provided with about 8 conical teeth normal in shape; prepyloric ossicle with 5–7 teeth along each postero-lateral margin ....*Penaeus stylirostris* STIMPSON.

I_2 Rostrum furnished with 8–9 teeth above, 2 ones below; adrostral carina reaching below epigastric spine; longer antennular flagellum as long as first segment of the peduncle; fifth pereiopod of female has no strikingly developed coxal plate; median lobe of petasma truncate at apex which is greatly exceeded by pointed tip of lateral lobe; thelycum rather simple: sternite between fourth pereiopods has a conspicuous concavo-convex cusp with convex surface forward, the last thoracic sternite furnished with a pair of thin walls a about midway; distal piece of appendix masculina about 2.2 times as lon as wide; zygocardiac ossicle furnished with about 28 closely set extraord narily developed teeth; prepyloric one carries 14–16 pointed teeth on eac postero-lateral edge ....*Penaeus vannamei* BOONE

A_3 Adrostral groove shallow, becomes gradually shallower backward and vanished abou below epigastric tooth; hepatic and post-ocular carinae absent at all ....**P. orientalis grou**

J_1 Postrostral carina runs posteriorly to about middle of carapace, upper bord slightly convex or almost horizontal; endopodite of maxillula three-segmente third pereiopod attains near tip of scaphocerite; median lobe of petasma blun pointed at apex and extends somewhat beyond distal margin of lateral lol seminal receptacle suboval in outline, a little longer than wide; rostrum arm with 7–9 teeth above, 3–5 ones below ....*Penaeus orientalis* KISHINOUY

J_2 Postrostral carina extends to about six-sevenths of carapace, upper border so what triangular or considerably convex in profile; endopodite of maxillula tw segmented; third cheliped stretches beyond apex of antennal scale by at le about half of chela; median lobe of petasma rounded at apex, extending as as distal margin of lateral lobe

K_1 Rostrum with 7–8 teeth above, and 4–6 below; upper border of postrost carina considerably convex in profile; dactylus of third maxilliped of m from 1.5 to 2.7* times as long as propodus; apical boss of anterior pi of thelycum comparatively small, two-ninths as wide as seminal recept ....*Penaeus penicillatus* ALCO

K_2 Rostrum armed with 8–9 teeth above, and 4–5 below; upper border of rostral crest considerably high and triangular in profile; dactylus of t maxilliped of adult male 0.5–0.6 times the length of propodus; apical boss anterior piece of thelycum comparatively large, about two-sevenths the w of seminal receptacle ....*Penaeus merguiensis* DE M

K_3 Rostrum with 7–9 teeth above, and 4–5 below; postrostral crest consider high and somewhat triangular in profile; dactylus of third maxilliped of a male about as long as propodus ....*Penaeus indicus* H. MILNE-EDWA

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* According to ALCOCK (1906, p. 8).

Penaeus japonicus BATE

(Figs. 1, *P*; 11, *A*; 12; 14, *B*; 15, *A–F*; 20, *C*; 24, *A–C*; 49, *A*; 57; 58, *A*; 67, *I–K*; 70; 71, *A* and *G*; 73, *A* and *G*; 77, *M*; 106; 107; 108; 111)

Penaeus japonicus, NOBILI, 1906, p. 10; DE MAN, 1911, p. 107; BALSS, 1914, p. 13; PARISI, 1919; p. 65; MAKI and TUTIYA, 1923, pp. 26–27, Pl. 1, fig. 3; HIRUMA, 1925, p. 421; SCHMITT, 1926, pp. 366 and 367; OSADA, TANIZAKI and NAKAZAWA, 1931, pp. 2–3, Pl. 1, upper; YU, 1936 a, p. 168; 1936 b, pp. 85–86; YOSHIDA, 1941, pp. 9–10, Pl. 1, text-fig., 2.

Penaeus canaliculatus OLIV. var. *japonicus*, BATE, 1888, p. 245, Pls. 31 and 32, fig., 4, and Pl. 37, fig., 2; ALCOCK, 1905, p. 514; VILLALUZ and ARRIOLA, 1938, pp. 37–38.

Penaeus canaliculatus, DE HAAN, 1850, p. 190; ORTMANN, 1890, p. 488, Pl. 36, fig., 2a, b; KISHINOUYE, 1900, pp. 6 and 11, Pls. 1 and 7 fig., 1, 1 a–c; RATHBUN, 1902, p. 37.

Carapace with supra-orbital, antennal and hepatic spines, the first is the smallest and the second the largest; hepatic located below middle between ultimate and penult rostral spines. Gastro-frontal groove deep and broad with bifurcate extremity, extends to about a sixth of carapace. Orbito-antennal groove also deep and broad, but gradually narrowed posteriorly meeting with cervical and hepatic grooves in front of hepatic spine. Cervical one narrow, runs posteromedially, reaches about midway toward two-thirds of median line of carapace. Hepatic groove narrow as is the case with cervical one; anterior half curves obliquely downward, extending a little behind antero-lateral margin of carapace; posterior half runs horizontally backward attaining below upper end of cervical groove. Postocular, gastro-orbital, antennal, cervical and hepatic carinae well-defined. Pterygostomian margin rounded. Abdomen dorsally carinated posterior to middle of fourth somite, insisted at posterior end of each dorsomedian carina of fourth and fifth somites. Sixth pleonic somite furnished on each lateral surface with three cicatrices arranged in a longitudinal row, the last one of which is less defined than others or sometimes not recognizable.

Mandibular palp strongly depressed, two-jointed, stretching to base of basicerite (Fig. 14, *B*); first joint invertedly triangular in outline; second remarkably excavated on distal outer margin, a little less than twice as long as wide measured at the widest region, and about 2.5 times the length of basal one (Fig. 12, *B*). Maxillula made up of two inner laciniae and an endopodite; the latter segmented into three, distally slender, proportions in length to the last segment: basal 1.5, intermediate 0.6; basal segment foliaceous, distally decreasing in width, provided with a prominent bristle on subterminal anterior margin and a protuberance with broadly rounded apex near base of posterior margin. First maxilliped is of Type–H_{2a}; endopodite slender, divided into five, gradually diminishing in size toward tip; proportions in length to the flagellum a little longer than the peduncle; fifth pereiopod of female has a strikingly developed coxal plate; median lobe of petasma bluntly pointed at apex, reaching slightly beyond tip of lateral lobe; the last thoracic sternite provided with a prominent pyramidal upheaval; distal piece of appendix masculina thrice as long as wide; zygocardiac ossicle provided with about 8 conical teeth normal in shape; prepyloric ossicle with 5–7 teeth along each postero-lateral margin ....*Penaeus stylirostris* STIMPSON.

I$_2$ Rostrum furnished with 8–9 teeth above, 2 ones below; adrostral carina reaching below epigastric spine; longer antennular flagellum as long as first segment of the peduncle; fifth pereiopod of female has no strikingly developed coxal plate; median lobe of petasma truncate at apex which is greatly exceeded by pointed tip of lateral lobe; thelycum rather simple: sternite between fourth pereiopods has a conspicuous concavo-convex cusp with convex surface forward, the last thoracic sternite furnished with a pair of thin walls at about midway; distal piece of appendix masculina about 2.2 times as long as wide; zygocardiac ossicle furnished with about 28 closely set extraordinarily developed teeth; prepyloric one carries 14–16 pointed teeth on each postero-lateral edge ....*Penaeus vannamei* BOONE.

A$_3$ Adrostral groove shallow, becomes gradually shallower backward and vanished about below epigastric tooth; hepatic and post-ocular carinae absent at all ....**P. orientalis group.**

J$_1$ Postrostral carina runs posteriorly to about middle of carapace, upper border slightly convex or almost horizontal; endopodite of maxillula three-segmented; third pereiopod attains near tip of scaphocerite; median lobe of petasma bluntly pointed at apex and extends somewhat beyond distal margin of lateral lobe; seminal receptacle suboval in outline, a little longer than wide; rostrum armed with 7–9 teeth above, 3–5 ones below ....*Penaeus orientalis* KISHINOUYE.

J$_2$ Postrostral carina extends to about six-sevenths of carapace, upper border somewhat triangular or considerably convex in profile; endopodite of maxillula two-segmented; third cheliped stretches beyond apex of antennal scale by at least about half of chela; median lobe of petasma rounded at apex, extending as far as distal margin of lateral lobe

K$_1$ Rostrum with 7–8 teeth above, and 4–6 below; upper border of postrostral carina considerably convex in profile; dactylus of third maxilliped of male from 1.5 to 2.7* times as long as propodus; apical boss of anterior piece of thelycum comparatively small, two-ninths as wide as seminal receptacle ....*Penaeus penicillatus* ALCOCK.

K$_2$ Rostrum armed with 8–9 teeth above, and 4–5 below; upper border of postrostral crest considerably high and triangular in profile; dactylus of third maxilliped of adult male 0.5–0.6 times the length of propodus; apical boss of anterior piece of thelycum comparatively large, about two-sevenths the width of seminal receptacle ....*Penaeus merguiensis* DE MAN.

K$_3$ Rostrum with 7–9 teeth above, and 4–5 below; postrostral crest considerably high and somewhat triangular in profile; dactylus of third maxilliped of adult male about as long as propodus ....*Penaeus indicus* H. MILNE-EDWARDS.

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* According to ALCOCK (1906, p. 8).

Penaeus japonicus BATE

(Figs. 1, *P*; 11, *A*; 12; 14, *B*; 15, *A–F*; 20, *C*; 24, *A–C*; 49, *A*; 57; 58, *A*; 67, *I–K*; 70; 71, *A* and *G*; 73, *A* and *G*; 77, *M*; 106; 107; 108; 111)

Penaeus japonicus, NOBILI, 1906, p. 10; DE MAN, 1911, p. 107; BALSS, 1914, p. 13; PARISI, 1919; p. 65; MAKI and TUTIYA, 1923, pp. 26–27, Pl. 1, fig. 3; HIRUMA, 1925, p. 421; SCHMITT, 1926, pp. 366 and 367; OSADA, TANIZAKI and NAKAZAWA, 1931, pp. 2–3, Pl. 1, upper; YU, 1936 a, p. 168; 1936 b, pp. 85–86; YOSHIDA, 1941, pp. 9–10, Pl. 1, text-fig., 2.

Penaeus canaliculatus OLIV. var. *japonicus*, BATE, 1888, p. 245, Pls. 31 and 32, fig., 4, and Pl. 37, fig., 2; ALCOCK, 1905, p. 514; VILLALUZ and ARRIOLA, 1938, pp. 37–38.

Penaeus canaliculatus, DE HAAN, 1850, p. 190; ORTMANN, 1890, p. 488, Pl. 36, fig., 2a, b; KISHINOUYE, 1900, pp. 6 and 11, Pls. 1 and 7 fig., 1, 1 a–c; RATHBUN, 1902, p. 37.

Carapace with supra-orbital, antennal and hepatic spines, the first is the smallest and the second the largest; hepatic located below middle between ultimate and penult rostral spines. Gastro-frontal groove deep and broad with bifurcate extremity, extends to about a sixth of carapace. Orbito-antennal groove also deep and broad, but gradually narrowed posteriorly meeting with cervical and hepatic grooves in front of hepatic spine. Cervical one narrow, runs posteromedially, reaches about midway toward two-thirds of median line of carapace. Hepatic groove narrow as is the case with cervical one; anterior half curves obliquely downward, extending a little behind antero-lateral margin of carapace; posterior half runs horizontally backward attaining below upper end of cervical groove. Postocular, gastro-orbital, antennal, cervical and hepatic carinae well-defined. Pterygostomian margin rounded. Abdomen dorsally carinated posterior to middle of fourth somite, insisted at posterior end of each dorsomedian carina of fourth and fifth somites. Sixth pleonic somite furnished on each lateral surface with three cicatrices arranged in a longitudinal row, the last one of which is less defined than others or sometimes not recognizable.

Mandibular palp strongly depressed, two-jointed, stretching to base of basicerite (Fig. 14, *B*); first joint invertedly triangular in outline; second remarkably excavated on distal outer margin, a little less than twice as long as wide measured at the widest region, and about 2.5 times the length of basal one (Fig. 12, *B*). Maxillula made up of two inner laciniae and an endopodite; the latter segmented into three, distally slender, proportions in length to the last segment: basal 1.5, intermediate 0.6; basal segment foliaceous, distally decreasing in width, provided with a prominent bristle on subterminal anterior margin and a protuberance with broadly rounded apex near base of posterior margin. First maxilliped is of Type–H_{2a}; endopodite slender, divided into five, gradually diminishing in size toward tip; proportions in length to the marked change during the growth. Trend of relative length, as referred to carapace, of the last joint ascends linearly for specimens smaller than 40 mm in carapacial length (ca. 140 mm in body-length), but turns a little horizontally for specimens larger than those given above (Fig. 107, *A*). Proportion of length of the last joint to that of carapace is 0.1 in smaller specimens of both sexes, and 0.09 and 0.05 in larger specimens of male and female respectively.

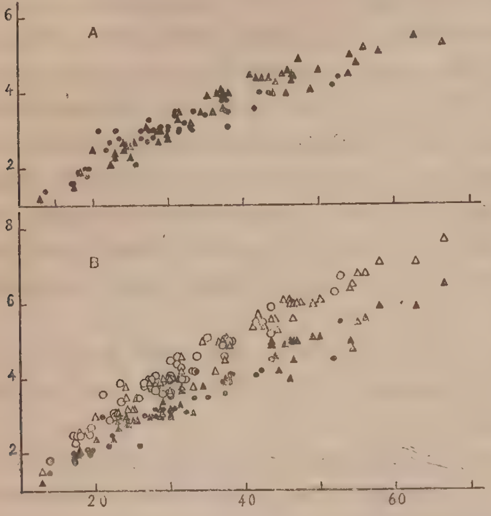

Fig. 107. Showing dimensions (in mm) of the last segment of third maxilliped (*A*), movable finger (solid marks) and palm (soft marks) of third cheliped (*B*) of *Penaeus japonicus* in relation to carapace-length. Circles, male; triangles, female.

Relative growths of all the pereiopods in regard to carapace-length are positively isogonic irrespective of sex (Fig. 111, *E–I*). Proportion i length to carapace is abou 0.7 in the first, 0.9 in th second, 1.2 in the third an fifth, and 1 in the fourt pereiopods.

Metamorphosis of carapace: At a post-larval stage with a lengt of 17 mm long, supra-orbital, antennal and hepatic spines exist alread though the first is very minute. Orbito-antennal, cervical, and hepati grooves are defined. Adrostral grooves reach about three-fifths of cara pace, but gastro-frontal not differentiated whatever (Fig. 108, *A* and *A′*

In a little advanced stage, 22 mm long, the most remarkable chang is that the adrostral grooves are much extended backwards. The orbito antennal groove gets more pronounced. But the gastro-orbital carin does not make its appearance yet (Fig. 108, *B* and *B′*).

When the animal attains a length of 32 mm, the adrostral groov are found reaching a little in advance of posterior margin of carapa as in adult form, although they are still shallow in posterior subterm nal portions. The median groove lying on the post-rostral carina appea at first as a shallow depression ranging from about middle to four-fift of carapce in extent. The gastro-frontal groove and carina are fou considerably developed already (Fig. 108, *C*).

Upon passing into a stage, 58 mm in body-length, the carapace a sumes its nearly adult form (Fig. 108, *D* and *D′*).

The metamorphosis of the apparatus of this prawn has of late be investigated by HUDINAGA (1942, pp. 50–52). Our result mostly agre with that of him. However, it should be mentioned that the carapace of the present species intimately resembles that of *Penaeus monodon* and its congener (in which the gastro-frontal carina and groove are absent, and the adrostral grooves extend to only about middle of carapace) in the post-larval stage, and undergoes gradual transformation with the growth. Thus the carapace of *japonicus*-type may be considered as specialized higher than that of *monodon*-type.

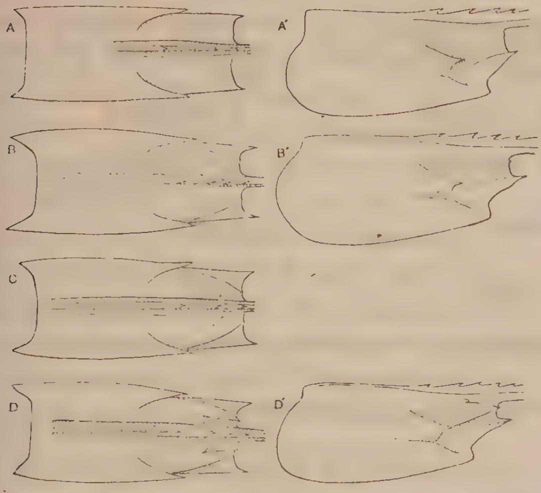

Fig. 108. Metamorphosis of carapace of *Penaeus japonicus*, male. *A–D*, dorsal view; *A′–D′*, lateral view. *A* and *A′*, 17 mm in body-length, ×8.8; *B* and *B′*, 22 mm long, ×4.8; *C*, 32 mm long, ×2.8; *D* and *D′*, 58 mm long, ×1.6.

Burkenroad (1934, p. 76) says "it is impossible to say whether or not the absence of gastro-frontal carina is primitive for the genus". But it is obvious that the absence of the crest is primitive, inasmuch as the crest appears secondarily as noted above.

Penaeus japonicus bears a strong resemblance to *Penaeus canaliculatus* Olivier. But it has been believed that the following characters are important for the demarkation of the present species from the latter by Bate and De Man, viz., (1) the telson has three pairs of lateral spines (Bate, *op. cit.*, p. 245); and (2) the fingers of the third pereiopods somewhat longer than palm (De Man, *op. cit.*, p. 108). Therefore attention especially was directed to these items during the course of the present investigation with the results as follows:—the armatures of the telson are found without exception to exist in the specimens dealt with; and the fact designated by De Man is true for Japanese specimens, at least larger than 12.8 mm in carapace-length (47 mm long) as shown in Fig. 107, *B*), in which the relative growths, as referred to carapace, of both the fingers and palm are to be seen clearly separated.

The specimens examined agree well with description and figures of De Man and others, but differ from the original description of Bate in five points as given in the following Table 24.

Table 24.

Items	Present author	BATE
(1) Abdomen	dorsally carinated posterior to middle of fourth somite	dorsally carinated in both fifth and sixth somites
(2) Maxillulary palp	3—segmented	2—segmented
(3) Endopodite of first maxilliped	5—segmented	4—segmented
(4) Pleurobranchiae of second thoracic segment	absent	present
(5) Podobranchiae of second thoracic segment	present	absent

Penaeus latisulcatus KISHINOUYE

(Figs. 1, *Q*; 7, *E*; 15, *G-L*; 20, *B*; 24, *D* and *E*; 39; 49, *J*; 56; 58, *B*; 67, *A-D*; 73, *B* and *H*; 77, *O*; 109, middle; 111).

Penaeus latisulcatus, KISHINOUYE, 1900, pp. 7, 12 and 13, Pl. 2, fig. 2 and Pl. 7 fig. 2. PARISI, 1919, p. 69; RATHBUN, 1902, p. 37; DE MAN, 1911, pp. 13-14; OSADA, TANIZAKI and NAKAZAWA, 1931, pp. 4-5, Pl. 2, upper (right); YOSHIDA, 1941, p. 9, Pl. 11, fig. 1.

Peneus latisulcatus, MAKI and TUTIYA, 1923, pp. 28-29, Pl. 2, fig. 1.

Rostrum styliform, slightly recurves upward in distal one-third, reaching to or beyond tip of antennular peduncle, about half as long as carapace. Carapace closely resembles that of *Penaeus japonicus*, but only exception is that postrostal carina as wide as adrostral carina. Abdomen dorsally carinated backward to about midway of fourth somite, the carina of sixth somite ends in a small sharply pointed spine; sixth somite about 1.3 times as long as wide and about half the length of carapace, furnished with three well marked cicatrices arranged in a longitudinal row on each lateral surface, and a spinule directed postero-ventrally a little in front of posterior end of each inferior margin. Telson tapering into an acute tip, about 2.6 times as long as wide, a little more than half the length of carapace. Prosartema reaching slightly beyond far end of basal segment of antennular peduncle. Stylocerite attains about middle of first joint of antennular peduncle. Antennular flagella asymmetrical in length; upper flagellum longer than lower one, and somewhat less than half the length of antennular peduncle. Antennal scale surmounts a little beyond distal end of antennular peduncle, about two and half times as long as wide measured at base, furnished with considerably thickened and well calcified outer margin which is slightly convex and ending in an acuminate spine exceeded by bluntly pointed lamella. Basicerite has a minute spine directed antero-ventrally.

Mandible belongs to Type–E_3; palp segmented into two, basal segment is of an inverted triangle in outline, about as long as wide measured in the broadest region; distal one broad with rounded apex, markedly excavated on antero-lateral margin, a little less than twice as long as wide, about three times the length of first joint (Fig. 7, *E*). Maxillula with three-jointed endopodite. Maxilla has two strips on inner side, each of the two distally divided into two. First maxilliped carries five-segmented endopodite as in *Penaeus japonicus*. Second maxilliped pediform but considerably depresed, inverted J-shaped, with carpus strongly curved inward and the last two joints directed backward; meropodite lamellar in inner about half, nearly 2.2 times as long as wide; exopodite extends to far end of carpocerite. Third one slender, reaches to distal edge of first segment of antennular peduncle, provided with an exopodite reaching about midway of carpocerite, proportions in length to dactylus: ischium 2.9, merus 2.4, carpus 2.3 and propodus 1.8.

First cheliped reaches far end of carpocerite, proportions in length against movable finger: ischium 1.0–1.2, merus 1.5–1.8, carpus 1.4–1.7, palm 0.6–0.8. Second one surpassing distal margin of carpocerite by entire chela, proportions in length to movable finger: ischium 0.9–1.2, merus 1.9–2.1, carpus 2.5–2.8, palm 0.5–0.7. Third one reaching to far end of second joint of antennular peduncle, rations in length to finger: ischium 1.1–1.3, merus 2.1–2.4, carpus 3.6–4.0, and palm 0.7–0.8; meropodite about 5.8 times as long as wide. Fourth pereiopod stretches to or beyond distal edge of basicerite, proportions in length against dactylus: ischium 1.2–1.4, merus 2.0–2.6, carpus 1.7–2.0, propodus 1.4–1.6. Fifth one somewhat longer than fourth one, reaches to about distal margin of basicerite as is the case with fourth limb, proportions in length to dactylus: ischium 1.3–1.5, merus 2.5–2.9, carpus 2.3–2.5 and propodus 1.4–1.7; meropodite about 4.6 times as long as wide.

Appendix masculina is of Type–O_1, more or less triangular in outline, with slightly convex inner and rounded distal margins, about 1.6 times as long as wide, fringed with thickly set setae along almost entire inner, distal and outer margins, but anterior surface devoid of setae and even hairs (Fig. 58, *B*).

Petasma very similar to that of *Penaeus japonicus*, but a remarkable difference being that the protuberance found at distal end of median lobe much smaller (about half) than that of *P. japonicus* (Fig. 24, *D* and *E*).

Thelycum made up of anterior and posterior pieces; anterior one is a well calcified upheaval with a bifurcate apical projection, lying on sternite between fourth pereiopods; posterior one rather calcified, subrectangular (somewhat shorter than wide); seminal receptacle composed of two lateral lobes with broadly rounded anteromedian margins, each of the lobes more or less medially overlapping each other. (Fig. 49, *J*).

Cardiac plate provided on inner surface with a longitudinal series which consists of 27–28 equidistant spinules (Fig. 77, *O*). Cardiac, pterocardiac and prezygocardiac ossicles intimately resemble those of *Penaeus japonicus* in general respects. Urocardiac one somewhat slenderer than that of *Penaeus japonicus*, bearing bluntly pointed anterior end and a pair of projections with bluntly pointed apex directed outward on each lateral sides of anterior subterminal portion (Fig. 73, *B*). Zygocardiac one armed on inner surface with several pointed teeth arranged in a row along its median line, the first one of which is the largest (Fig. 77, *O*). Prepyloric well-defined, subpentagonal in upper view, tapering into a point in distal two-fifths, armed along each posterolateral edge with about seven pointed teeth which get gradually larger toward distal end of the ossicle (Fig. 73, *B* and *H*).

The description given above is derived from 26 males, 35.5–165.0 mm long (10.4–46.4 mm in carapace-length) and 8 females, 38.0–137.1 mm long (10.4–40.1 mm in carapace-length) secured from the following localites: Kominato, Tiba Pref., Miya Aiti Pref., Nagasaki and South China Sea.

Distribution: Tokyo Bay, Kagoshima (Kishinouye); Nagasaki (Rathbun); West coast of Ceram Reef, near North-point of Saleyer Reef, Nusa-Lant-island (46 m deep), North-point of Tiur-Island Reef, (De Man); Pescadores-Islands, Takao, Nagasaki, Misaki, Tu, Yokohama (Balss); Taiwan (Maki and Tutiya); South-East coast of Korea (Yoshida); Sashiki, Kumamoto Pref. (Osada & Nakazawa).

Note: The count of upper rostral spines varies within a limit of 9 to 12, but mostly 10 in number. Posterior 4 or 5 of the armature are located on carapace. On the other hand, the lower spine is invariably single in number. No sexual difference is found to exist in such items at all.

As seen in Fig. 111, *A*, the relative growth, in relation to carapace length, of rostrum is almost linear in trend as is the case with *Penaeus japonicus*, but somewhat smaller than that of the said species.

The growth of the median groove lying on the postrostral carina is proportional to that of carapace-length irrespective of sex, and the ratio about 0.53 on average (Fig. 111, *C*). The length of stylocerite increases with advance of growth of carapace. The trend linearly ascends in smaller specimens than 35 mm in carapace-length and the ratio to length of carapace is about 0.24, but it does not so rapidly go up in larger examples than given above and the ratio is about 0.22 as is the case with *Penaeus japonicus* (Fig. 111, *B*).

Third maxilliped differs in configuration with sex, and remarkable difference is found in the last two joints. The penult segment of male is provided on upper distal outer margin with a protuberance which bears at apex a tuft of long hairs reaching to subtermital portion of dactylus, and the last segment has a longitudinal depression running on dorsal outer surface as in *Penaeus japonicus*. But those segments in question of female are ordinary in general aspect, and the ultimate joint relatively longer than that of male.

Such sexual modification given above, first appears when the animal attains about 80 mm in length of body as illustrated in Fig. 15, *G–L*.

Remarkably enough, the relative growths of all the pereiopods in relation to carapace-length are positively isogonic irrespective of sex and age, and quite accord with those of *Penaeus japonicus* (Fig. 111, *D–I*).

The metamorphoses of appendix masculina (Fig. 67, *A–D*) and thelycum (Fig. 56, *A* and *B*) of the present species are already dealt with in the general part of this paper.

All the specimens so far as examined quite tally with the description and figures of this species given by KISHINOUYE and other previous investigators.

The present species closely related to *Penaeus plebejus* HESS (DE MAN, 1911, pp. 108–111 and SCHMITT, 1926, pp. 367–370, Pl. 65, figs. 1–4, and Pl. 68, fig. 1), but separable from the latter by having the following characters:—

(1) the rostrum without a pair of secondary rostral grooves; (2) the gastro-frontal groove bifurcate; (3) the stylocerite reaching the middle of first segment of antennular peduncle; (4) the median lobe of petasma ends in a protuberance directed ventrally, and the anterior piece of thelycum has a pair of prominent apical horns.

LANCHESTER'S *Penaeus canaliculatus*, OLIVIER var.? (1901, p. 571, Pl. 34, fig. 5) is identified with the present species by DE MAN (*op. cit.* p. 108). In reality the thelycum of LANCHESTER'S two specimens, 50.5 mm and 59.0 mm long, according to his illustration, is closely related to that of the present specimens. But the anterior piece of the apparatus of his specimens differs in feature from that of our specimens: the armature of the former is provided with somewhat trifid apex instead of being bifid. It is my regret that I cannot ascertain whether the variation is caused by difference of age or not, since my material is not represented by such specimens similar in size as those of LANCHESTER. So that I hesitate to identify both the species in question with the present species. It should be mentioned herein that the anterior piece of thelycum of LANCHESTER'S *Penaeus canaliculatus* stands apart from that of all other related forms, viz., *Penaeus plebejus* HESS and *Penaeus lon-*

gistylus KUBO. Consequently if the difference stated above is specific, a new name should be given to LANCHESTER's species.

Penaeus longistylus KUBO

(Figs. 7, *A*; 24, *F* and *G*; 49, *I*; 58, *E*; 73, *C* and *I*; 77, *Q*; 109-111).

Penaeus longistylus, KUBO, 1943, pp. 200–201, fig., 1.
Penaeus sp., KUMADA, 1941, Pl. 132.

Diagnosis of the present species was given already by the present writer as cited above. The following description, is penned in order to supplement the original.

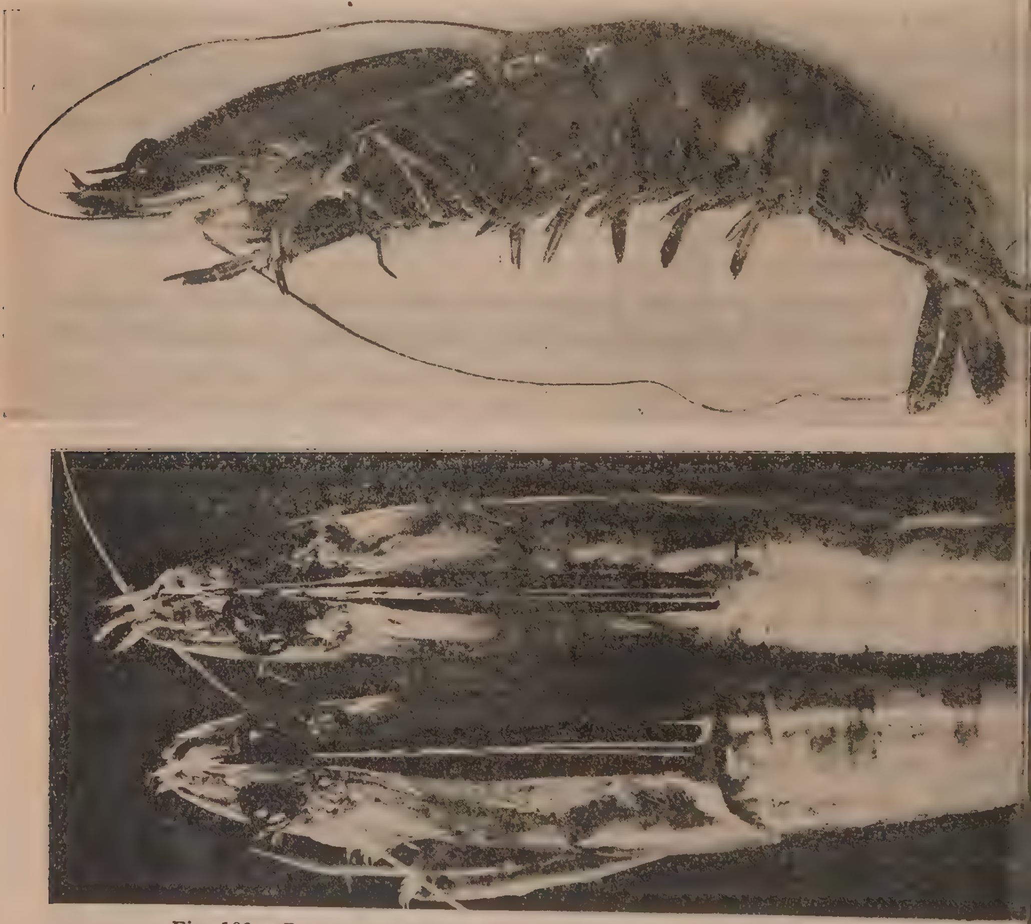

Fig. 109. *Penaeus longistylus*, female, 151 mm in body-length without rostrum (upper and lower) and *Penaeus latisulcatus*, male, 165 mm in body-length without rostrum (middle). Upper, photo. by the late Mr. Yoshizô HIBI. Middle and low, by the present author.

Rostrum slightly recurves upward in distal about one-third; upper border armed with 11 teeth, fifth one of which is set above frontal margin of carapace; lower one has a tooth at about two-thirds. Postrostral carina somewhat convex, highest at about middle of carapace. Adrostral groove remarkably broad, about one and half times the width of postrostral carina (Fig. 109, lower). Abdominal segments, exclusive of third and sixth ones, notched at middle of each posterior margin of lateral plates as in *Penaeus japonicus* and *Penaeus latisulcatus*. Sixth pleonic somite has a sharp dorsomedian carina which ends in an acuminate spine directed posteroventrally, a sharply pointed minute spine directed backwards at each postero-inferior angle, and ill-defined three cicatrices on both lateral walls. Antennal scale about two and half times as long as wide measured in the broadest region. Mandible well developed; molar process flat and subrectangular on masticatory surface, with rather sharp inner margin which is somewhat produced medially in posterior half; incisor one antero-ventrally projected from postero-outer angle of molar process, rather thin with a notch at about two-thirds.

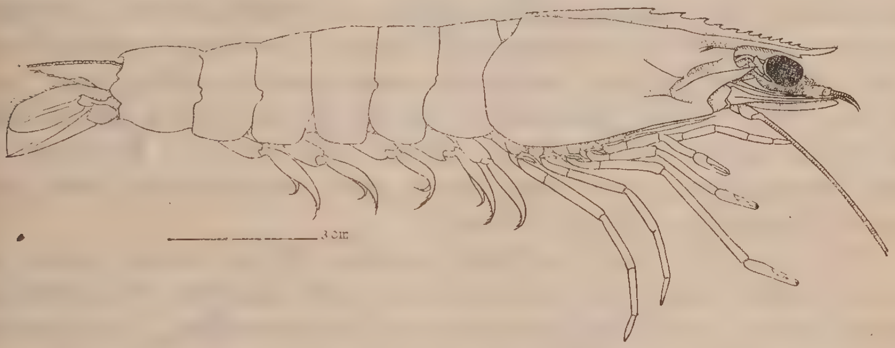

Fig. 110. *Penaeus longistylus* KUBO, female, 151 mm long.

Mandibular palp foliaceous, two-segmented; basal segment is of an inverted triangle in outline, somewhat wider than long measured in the widest region; the other broad with somewhat convex inner and much convex outer margins, and with bluntly pointed tip directed obliquely sidewise, about 0.7 times longer than the greatest width, and ca. 3.3 times the length of basal semgent (Fig. 7, *A*). Maxillula provided with three-segmeted endopodite. Maxilla bears unsegmented endopodite, ear-shaped exopodite, and two gnathobasic laciniae, each of which is divided into two strips. First and second maxillipeds closely resemble those of *Penaeus japonicus* and *Penaeus latisulcatus*. Third maxilliped pediform, segmented into seven; proportions in length to dactylus: ischium 2.5 (♂), 2.3, (♀); merus and carpus 1.8 (♂), 1.6 (♀); and propodus 1.3 (♂), 1.1 (♀). First pereiopod attains distal margin of carpocerite, palm about half the length of movable finger. Second surpassing tip of preceding cheliped by finger and about half of palm, palm ca. 0.65 times as long as movable finger.

Appendix masculina similar to that of *Penaeus japonicus*, spatulate with rounded apex, about twice as long as wide, clad with short setae on anterior surface in distal half and along almost entire margins (Fig. 58, *E*).

Petasma intimately related to that of *Penaeus latisulcatus* in general respects, but anterior tip of median lobe not ventrally turning (Fig. 24, *F* and *G*). Thelycum made up of anterior and posterior pieces as given in the previous paper; anterior one with bluntly pointed apex nearly reaching middle of penult sternite, about 2.5 times as long as wide; posterior one again consists of two lateral lobes which have straight median margins coming into contact with each other, and forming a seminal receptacle which is as long as wide and assumes the outline of an inverted dome (Fig. 49, *I*).

Cardiac plate provided on inner surface with about 28 sharply pointed equidistant spinules alined longitudinally (Fig. 77, *Q*). Cardiac, pterocardiac and prezygocardiac ossicles resembling those of *Penaeus japonicus*. Urocardiac rightangularly pointed at tip and furnished with a pair of obtusely pointed lateral processes directed outward near anterior end (Fig. 73, *C*). Zygocardiac carries a longitudinal series made up of four conical teeth on inner surface (Fig. 77, *Q*). Prepyloric as wide as urocardiac, armed with four or five pointed teeth along each postero-lateral edge (Fig. 73, *C* and *I*).

Colour in life: Body uniformly reddish. Third pleonic somite has a rather large cirular red pattern on each side, and first five abdominal pleura have a narrow vertical pattern of the same colour. Sixth pleuron also striped with a red band running from about center of lateral surface to postero-inferior angle (Fig. 109, upper).

The description given above is made from a male, 147.5 mm long (40.2 mm in carapace-length) and a female 151.0 mm long (44.0 mm), secured by the late Mr. Yoshizo HIBI (Captain of S. S. Syunkotsu-Maru) at a depth of 55 m off South-East coast of Hainan Island.

Note: The third maxilliped is sexually dimorphic as is the case with *Penaeus japonicus* and *Penaeus latisulcatus*. But the hairs forming the tuft on the distal outer edge of the propodus are shorter (reaching about middle of the dactylus), and the dactylus is slenderer than that of the two species given above.

The present species is very near to *Penaeus latisulcatus* KISHINOUYE (KISHINOUYE, 1900; and DE MAN, 1911, *op. cit.*) and *Penaeus plebejus* HESS. But it may be readily distinguished from the former by possession of the following characteristics:—(1) median groove laid down on the post rostral carina shorter (Fig. 111, *O*), and not reaching to the posterior ends of the adrostral grooves; (2) adrostral grooves about one and half times as broad as the postrostral crest instead of being about as wide as it; (3) stylocerite extending to far end of the first segment of the antennular peduncle (Figs. 110 and 111, *B*); (4) fifth pereiopod relatively longer (Fig. 111, *I*); (5) tip of the median lobe of the petasma not recurved downwards; (6) anterior piece of the thelycum simply pointed; (7) seminal receptacle assuming the outline of an inverted dome; (8) appendix masculina simply ovoid; and (9) prepyloric ossicle armed with four or five teeth on each postero-lateral margin. It differs from *Penaeus plebejus* by having following characters:—(1) postocular

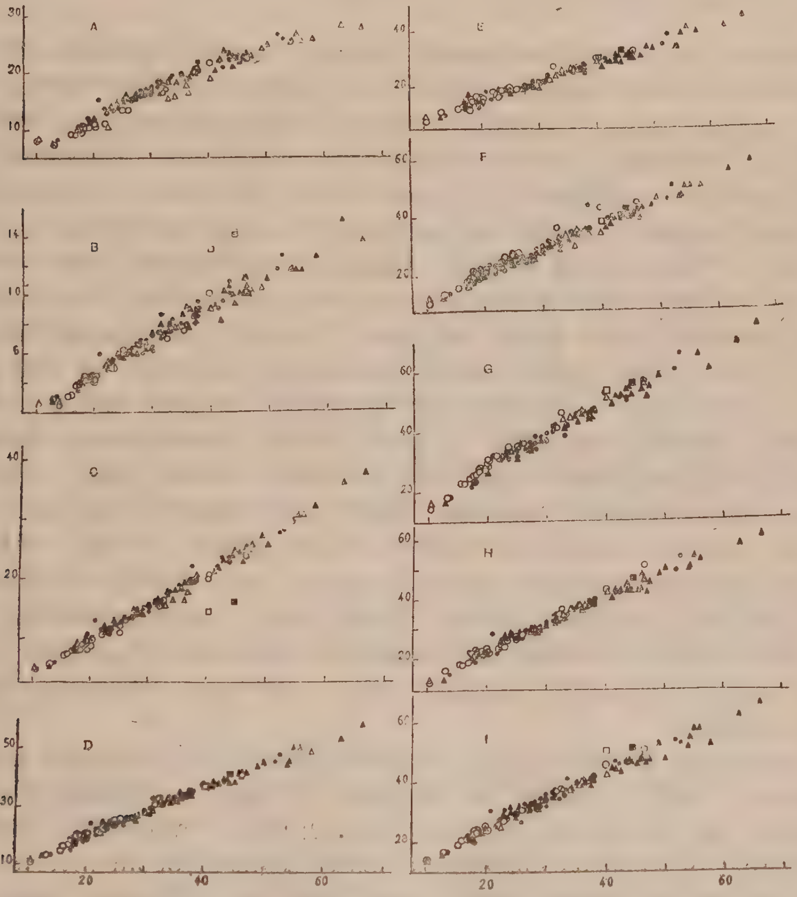

Fig. 111. Showing dimensions (in mm) of the rostrum (*A*), stylocerite (*B*), adrostral groove (*C*), third maxilliped (*D*), first cheliped (*E*), second leg (*F*), third leg (*G*), fourth leg (*H*), and fifth one (*I*) in relation to carapace-length. Solid marks, *Penaeus japonicus* and female of *Penaeus longistylus*; soft marks, *Penaeus latisulcatus* and male of *Penaeus longistylus*. Circles, male; triangles, female; squares, *Penaeus longistylus*.

groove bifurcate (2) median groove shorter and not extending to posterior end of adrostral grooves; (3) adrostral one about 1.5 times as wide as postrostral carina; and (4) anterior piece of thelycum simply pointed.

Penaeus brevirostris KINGSLEY

(Figs. 7, *G*; 20, *K*; 25, *D–F*; 49, *H*; 58, *L*; 74, *A* and *G*; 78, *D*).

Penaeus brevirostris, BURKENROAD, 1934, p. 75; RATHBUN, 1910, p. 146; HULT, 1938, p. 2.

Peneus brevirostris, SCHMITT, 1921, pp. 21–22, fig. 9.

Rostrum styliform, horizontally straight, hardly reaching to tip of antennular peduncle, unarmed above and below in distal third, Postrostral carina attains somewhat in front of posterior margin of carapace, furnished with barely defined median groove running backward from about middle of carapace to pesterior end of the carina. Adrostral groove rather narrow, as wide as post-rostral carina, stretching to posterior end of post-rostral carina. Gastro-frontal carina rather defined, and runs parallel with adrostral groove, reaching to one-fifth of carapace. Orbito-antennal groove broad and deep. Cervical and hepatic ones narrow. Gastro-orbital carina extends somewhat backward to post-orbital margin of carapace. Hepatic carina nearly straight directed anteroventrally reaching anteriorly a little behind antero-lateral border of carapace and posteriorly below the rearmost rostral spine. Pterygostomian angle rounded. Antennal, hepatic, and supra-orbital spines present, the last one minute and other two moderate in size. Abdomen dorsally carinated posterior to third segment, the carina of sixth segment ends into an acute spinule. Sixth pleonic somite somewhat longer than wide, about two-thirds the length of carapace, furnished with a spinule near each postero-inferior angle, and three cicatrices both on lateral surfaces.

Antennular flagella as long as first segment of antennular peduncle. Stylocerite hardly reaches to midway of basal antennular segment. Basicerite has no spinule on antero-lateral edge. Mandible closely resemble that of *Penaeus longistylus;* basal segment of an inverted triangle in outline, as long as wide; distal one ca. 0.7 times longer than wide, 2.7 times the length of, and half times wider than, the basal (Fig. 7, *G*). Maxillulary palp three-segmented; basal joint gradually decreasing in width toward apex, a little more than twice as long as wide measured near base, broadly excavated at two-thirds of anterior margin which has a large spiniform seta at three-fourths, and carries a protuberance near base of posterior margin; intermediate joint cylindrical, two and half times the width, a little less than a third the length of the basal and about a quarter the width of basal one; the last joint nine times as long as wide, thrice the length of intermediate one. Maxilla resembles that of *Penaeus japonicus*, *P. latisulcatus* and *P. longistylus*. Endopodite of first maxilliped five-segmented, proportions in length to the last segment: first 1.3, second 0.3, third 0.5, and fourth 1.

Appendix masculina subrectangular in outline, about a third longer than the greatest width, thickened on inner side, fringed with setae along outer and distal margins, naked on inner margin as well as anterior surface (Fig. 58, *L*).

Petasma: each median lobe has a well developed protuberance overhanging anterior margin of lateral lobe as in *Penaeus japonicus*, but not thickened, has an auriculate appendage on each subterminal lateral surface; lateral lobe furnished with sparsely set setae on outer surface in about distal half (Fig. 25, *D–F*).

Thelycum: a calcified median upheaval with fig-shaped apical projection exists on sternite between fourth pereiopods. Seminal receptacle circular in outline, made up of two ill-calcified lateral lobes, each of which comes into contact with each other in posterior three-fourths and overlaps some posterior portion of the median upheaval (Fig. 49, *H*).

Cardiac plate armed on inner surface with 29 equidistant spinules arranged in a longitudinal series (Fig. 78, *D*). Cardiac, pterocardiac, prezygocardiac and urocardiac ossicles very similar to those of *Penaeus japonicus*. Zygocardiac furnished with about ten rather closely set conical teeth alined longitudinally, the foremost one much larger than other (Fig. 78, *D*). Prepyloric provided on each postero-lateral margin with about ten pointed teeth which become gradually larger in size backward (Fig. 74, *A* and *G*).

Described from a male, 130 mm long (34 mm in carapace-length) and a female, 114 mm long (30 mm), obtained from Gulf of California on May 30, 1940.

Habitat: 27° 06′ *N.*; 110° 10′ *W.*; depth 45 fathoms; bottom, mud; water-temperature 27.5 C°.

Distribution: San Francisco Bay, California to Panama; Galapagos Islands (SCHMITT and HULT).

Note: The two specimens dealt with here well agree with description and figures given by SCHMITT, except the following points.

The rostrum of the present specimens reaches to tip of antennular peduncle, whilst the apparatus of the specimen described by SCHMITT is "falling short of antennular peduncle". Such difference may be, however, merely a fluctuation within one species.

The present species is closely allied to *Penaeus japonicus* but these two forms differ in principal characters as given in Table 25.

Table 25.

Items	*P. brevirostris*	*P. japonicus*
1. Rostum	armed below with 2 teeth	armed below mostly one
2. Adrostral groove	narrower	broader
3. Median groove of postrostral carina	hardly marked	well-defined
4. gastro-frontal groove	rather deep, not bifurcate	deep, bifurcate
5. Telson	unarmed	armed with 3 pair of lateral spines
6. Pereiopods from first to fifth	relatively longer; third leg reaches to far end of second segment of antennular peduncle	relatively shorter; third leg reaches to far end of basal segment of antennular peduncle
7. Median lobe of petasma	has a thin protuberance at apex, and a minute auriculate appendage on subterminal lateral surface	has a thickened protuberance at apex, and no auriculate appendage.
8. Seminal receptacle	made up of 2 lateral lobes, subcircular in outline	cylindrical with opening forward

BOONE's specimen (a large male), which was obtained from Indefatigable Island (Galapagos) and described as *Penaeus brevirostris* by her, greatly differs from our specimens in the following important points, viz., (1) adrostral carine extending to about midway of carapace (p. 107), (2) petasma widely separated at apex, and (3) abdomen dorsally carinated in fifth and sixth segments only.

It follows, therefore, that there is room for doubt as to whether or not her identification was really correct.

Penaeus teraoi sp. nov.

(Figs. 7, *F*; 20, *F*; 24, *N–P*; 49, *K*; 58, *G*; 73, *D* and *J*; 77, *S*; 112).

Shell glabrous. Rostrum sharply pointed at apex, reaching a little beyond tip of antennular peduncle, horizontal in proximal two-thirds but more or less elevated in the rest; upper border armed with 9 or 10 (mostly 10) teeth, posterior 4 of which are set on carapace, the foremost inserted at about two-thirds, while the hindmost stands at two-fifths of carapace, distance between the last and penult teeth ca. 2.5 times the distance between penult and antepenult ones; lower border furnished with 1 or 2 teeth at about two-thirds. Carapace closely resemble that of *Penaeus japonicus* and *Penaeus latisulcatus*, but postrostral carina somewhat higher and not medially grooved, and adrostral groove gets gradually narrowed posterior to middle of carapace and much narrower than postrostral crest. Abdomen has a sharply defined dorso-median carina running backward from one-third of fourth segment, the carina of sixth somite ends in an acute spine directed rearward, sixth somite about 0.3 times longer than wide, and half times the length of carapace, provided with three ill-defined cicatrices on each side and a spinule near each postero-inferior angle. Telson tapering into a sharply pointed tip, about three times as long as wide measured at base, somewhat shorter than sixth pleonic somite, and greatly exceeded by tip of inner uropods, furnished with clearly cut mid-dorsal groove and three pairs of movable spines on both sides posterior to about middle. Stylocerite reaches to or beyond midway of first segment of antennular peduncle as in *Penaeus latisulcatus*. Antennular flagella as long as the peduncle. Antennal scale somewhat surpassing tip of antennular peduncle; outer margin almost straight, ending in a sharply pointed spine which is well surmounted by distal margin of lamella. Basicerite has a minute spine on outer anterior edge. Mandible resembles that of *Penaeus longistylus*; palp extends to base of carpocerite, second segment about 1.6 times as long as wide, and about thrice the length of the first (Fig. 7, *F*). Maxillula, maxilla and all maxillipeds closely allied to those of *Penaeus japonicus*, *P. latisulcatus* and *P. longistylus*. Third maxilliped attains far end of basal segment of antennular peduncle; ratios in length to dactylus; ischium 2.8, merus and carpus 2.0, and propodus 1.5. First pereiopod reaching to base of carpocerite, armed with both basial and ischial spines, movable finger about 1.3 times as long as palm which is about half the length of carpus. Second slightly surmounts far end of carpocerite, carries well developed basial spine, dactylus by one-fifth longer than palm. Third reaches to midway of antennal scale, proportions in length to movable finger; ischium 1.5, merus 2.4, carpus 3.2, and palm

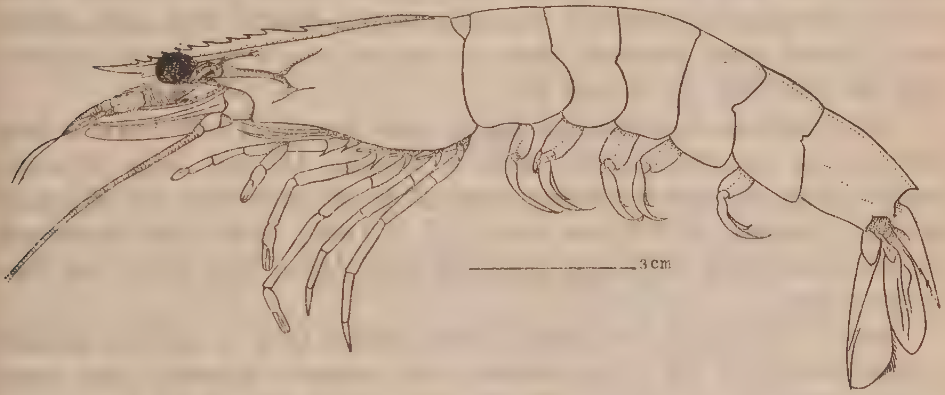

Fig. 112. *Penaeus teraoi* sp. nov. male, 140 mm in body-length.

1. Last two limbs extending nearly distal edge of basicerite. Fifth slightly longer than the fourth, proportions in length against dactylus: ischium and propodus 1.5, merus 2.5, and carpus 2.

Appendix masculina subelliptical in outline as in *Penaeus japonicus*, about 0.7 times longer than wide (Fig. 58, *G*).

Pteasma spout-like, closely similar to that of *Penaeus latisulcatus*, but tip of median lobe not produced into a protuberance (Fig. 24, *N–P*).

Thelycum: calcified median boss lying in front of seminal receptacle, markedly developed, provided with a lanceolate projection directed forward. Seminal receptacle made up of two lateral subrhombic lobes which come into contact with each other along median edges (Fig. 49, *K*).

Cardiac plate bears about 30 pointed spinules which are equidistantly arranged in a longitudinal row (Fig. 77, *S*), cardiac, pterocardiac and prezygocardiac ossicles similar to those of *Penaeus japonicus*. Zygocardiac armed with about 12 closely set conical teeth alined longitudinally, the first tooth of which remarkably larger than others (Fig. 77, *S*). Prepyloric furnished on each postero-lateral rim with about seven pointed teeth, proximal three or four of which are much smaller than the rest (Fig. 73, *D* and *J*).

The foregoing description is based upon a male (Type), 140 mm long (39.8 mm in caparace-length), and a female, 141 mm long (41 mm). Besides these, six males, ranging from 87 to 135 mm long (24–38.5 mm) and four females, 32–148 mm long (9.5–43.5 mm) were also examined. All specimens dealt with were obtained from Miya, Aiti Pref., by Mr. CENKITI ABE.

Note: The number of upper rostral spines is 9 or 10 as already written elsewhere. Of 12 specimens at the writer's disposal, four have 9, and eight have 10 spines. On the other hand, that of the lower ones is 1 or 2. Among all the specimens, six have 1 and the rest have 2 spines.

Remarkably enough, the degree of the upward inclination in distal about a third of the rostrum and the length of the antennular flagella tend to increase with advance of growth. The flagella are less than half as long as the antennular peduncle in those specimens smaller than at most 87 mm in length of body (24 mm in carapace-length).

Regarding the third maxilliped, sexual modification is evident in the last two joints. In male, the propodus bears a tuft rather long hairs, likewise that of *Penaeus japonicus* and *Penaeus latisulcatus*, and the dactylus is considerably thicker than that of female.

The species erected herein approaches nearer to *Penaeus latisulcatus* KISHINOUYE (*op. cit.*) than to any other, but it can be distinguished from *P. latisulcatus* as given in the following table. (Table 26).

Table 26.

Items	Present species	*P. latisulcatus*
1. Postrostral carina	lacks median groove	bears median groove
2. Adrostral groove	becomes remarkably narrower in posterior half (much narrower than postrostral crest	gets slightly narrower in posterior half (about as wide as postrostral crest)
3. Antennular flagella	as long as antennular peduncle	about half the length of antennular peduncle
4. Median lobe of petasma	without apical protuberance	carries a protuberance curved ventrally
5. Thelycum	anterior piece has a lanceolate apical projection, seminal receptacle as long as wide (measured at base)	anterior piece has a bifurcate apical projection, seminal receptacle shorter than wide (measured at base)
6. Cardiac plate	armed with about 30 spinules	armed with 26-27 spinules
7. Zygocardiac ossicle	provided with 12 teeth	furnished with 5 teeth

Penaeus monodon FABRICIUS

(Figs. 1, *F*; 7, *D*; 15, *M-T*; 20, *A*; 24, *H-J*; 38; 49, *B*; 54; 58, *C*; 67, *E-G*; 73, *E* and *K*; 77, N; 113).

Penaeus monodon, LATREILLE, 1803, p. 249; MILNE-EDWARDS, H; 1837, p. 416; BATE, 1881, p. 178; 1888, pp. 250-252, Pl. 34, fig., 1; MIERS, 1884, p. 15.

Peneus monodon, BOONE, 1935, pp. 87-91, text-fig., 5 and Pl. 22; ALCOCK, 1906, pp. 8-9, Pl. 1, fig., 1.

Penaeus ashiaka, KISHINOUYE, 1900, pp. 7 and 14, Pl. 3 and Pl. 7, fig., 4; RATHBUN, 1902, p. 38.

Penaeus semisulcatus, BALSS, 1914, p. 14; OSADA, TANIZAKI and NAKAZAWA, 1931, pp. 3-4, Pl. 1 (lower); YOSHIDA, 1941, p. 10, text-fig., 3 and Pl. 1, fig., 2.

Peneus semisulcatus, MAKI and TUTIYA, 1923, pp. 29-31, Pl. 1, fig., 2.

Penaeus semisulcatus paucidentatus, PARISI, 1919, pp. 65-66, Pl. 5, fig., 5.

Penaeus carinatus, DANA, 1852, p. 602, Pl. 40, fig., 2; WALKER, 1887, p. 112; KEMP, 1918, p. 294.

Rostrum proximally horizontal, barely curved upward in distal one third, hardly reaching to tip of antennular peduncle, 17 times the length of carapace, upper border armed with 7 teeth, posterior three of which are placed on carapace, the hindmost stands somewhat in front of middle of carapace, the fourth inserted a little in advance of frontal margin of carapace, and the foremost set at two-thirds; lower border tridentate, the first tooth located near midway and the last at three-fourths. Postrotral carina reaches a little in front of posterior margin of carapace, having well-defined median groove which ranges from posterior base of the rearmost dorsal tooth to posterior end of the carina. Adrostral, gastro-orbital, antennal, cervical and hepatic carinae well-defined, the second of which extends from anterior one-third of distance between orbital margin and hepatic spine to a little above hepatic spine.

Cervical sulcus very narrow, slightly shallower than orbito-antennal one, slopes up from upper base of hepatic spine to about middle of distance between center of carapace and base of hepatic spine. Hepatic one straight, more or less tilted antero-inferiorly, as narrow and deep as cervical groove, ranging from a point, which is somewhat postero-ventral to hepatic spine, to a site a little behind frontal margin of carapace, measuring about a fifth the length of carapace. Postorbital and pterygostomian angles rounded. Abdomen dorsally carinated backward to one-third of fourth somite, the carina of sixth somite ends in an acute spinule. Telson tapering into a point, about three times as long as wide, and 0.6 times as long as carapace, provided with deeply cut dorso-median furrow and no lateral armatures.

Prosartema well surpassing distal margin of eye. Stylocerite extends to middle of basal antennular segment. Antennular flagella subequal in length, somewhat more than half the length of the peduncle; outer one lamellar in proximal half and filamentous in the rest.

Oral appendages closely resemble those of *Penaeus japonicus* (Fig. 7, *D*). Third maxilliped reaches to or beyond distal margin of first antennular segment. First, fourth and fifth pereiopods reaching to or beyond distal edge of carpocerite. Second attains about middle of antennal scale. Third hardly extending to far end of intermediate antennular segment. Basial spine present on first and second pereiopods, but the ischial on second limb only. Proportions in length to dactylus run as follows:—

	Ischium	Merus	Carpus	Propodus
Third maxilliped	3.1	2.2	2.1	4.1
First pereiopod	1.1	1.5	1.6	6.1
Second „	1.2	2.0	2.6	6.6
Third „	1.2	2.1	3.6	7.8
Fourth „	1.2	2.1	1.7	7.0
Fifth „	1.3	2.4	2.0	7.1

Appendix masculina similar to that of *Penaeus japonicus*, but distal piece broader, about 1.3 times as long as wide (Fig. 58. *C*).

Petasma nearest to that of *Penaeus latisulcatus*, but the protuberance attached to apex of median lobe much smaller, and ventral margin of lateral lobe furnished with about seven spinules in subterminal portion (Fig. 24, *H–J*).

Thelycum consists of an elevation laid down on sternite between fourth pereiopods and seminal receptacle lying just behind the elevation.

The elevation well calcified, provided with an apical projection which assumes the outline of a crown. The receptacle composed of two ill-calcified lateral lobes, each of which ovoid in outline and a little narrowed anteriorly, extending from posterior edge of the last thoracic sternite to nearly posterior base of fourth pereiopod, about twice as long as wide, meeting with each other along median edge which is more or less recurved ventrally, and somewht overlaps the elevation with anteromedian edge (Fig. 49, *B*).

Cardiac plate armed with 21–23 spinules as is the case with *Penaeus japonicus*, and zygocardiac ossicle with 7–11 conical teeth (Fig. 77, fig., *N*). Prepyloric ossicle closely resembles that of *Penaeus longistylus*, furnished along posterior margin with three pairs of bluntly pointed teeth, besides a large median tooth (Fig. 73, *E* and *K*).

Described from a male, 143 mm long (37 mm in carapace-length) and a female 152 mm long (40 mm in carapace-length). In addition to these, 38 males, measuring 45–144 mm long (13–37 mm in carapace-length), and 48 females, 47.5–177.5 mm long (12.5–48.0 mm in carapace-length) were also examined.

Locality: Tokyo (fish market); Hatazawa, Chiba Pref., Miya, Aichi Pref., Sashiki, Kumamoto Pref., Tainan (Formosa); South coast of Borneo.

Distribution: Indes Orientales (LATREILLE); cotes de l'Inde (H. MILNE-EDWARDS); South of New Guinea (28 fathoms), off Panay, Philippine Islands (20 fathoms) (BATE); Mauritius (MIERS); Orissa and Ganjam (20–23 fathoms), off Indus Delta (30–72 fathoms), Martaban (20 fathoms), Madras and Pondicery (ALCOCK); Sumbawa (BOONE); Southern half of Japan (KISHINOUYE); Wakanoura, Nagasaki (RATHBUN); Takao, Pescadores, Sagami-Bay, Tokyo-Bay (BALSS); Sashiki, Kumamoto Pref., (OSADA and others); Chinkai, Katoku, Huzan (fish market) (Tyosen) (YOSHIDA); Taiwan (MAKI and TSUCHIYA); Yokohama (PARISI); Singgora (KEMP).

Note: The upper rostral spines vary from 6 to 8 (mostly 7) in number. Of 76 specimens, 3 have 6, 64 have 7, and 9 have 8. On the other hand, the number of the lower one ranges 2 to 4, but mostly (92%) 3. Thus the number of these spines is neither specifically invariable nor important for the recognition of species as formerly believed.

As given in the following table (Table 27), there is no relation between the number of these spines and lengths of rostrum and carapace. Their correlation coefficients computed were given already (Table 2).

Third maxillipeds of male remarkably differ from those of female as in *Penaeus japonicus*, *P. latisulcatus* and *P. longistylus* (Fig. 15, *M–T*). As to the dactylus, the longitudinal depression is observed already when the animal attains a length of 76 mm (Fig. 15, *O*). But the tuft of hairs lying on the distal margin of the propodus appears a little later

Table 27.

		upper rostral spines			
		6	7	8	f
Carapace-length (in mm)	7–13		1		1
	13–19		22	5	27
	19–25	2	16	1	19
	25–31		11	2	13
	31–37	1	5	1	7
	37–43		7		7
	43–49		2		2
	f	3	64	9	76

		lower rostral spines			
		2	3	4	f
Carapace-length (in mm)	7–13		1		1
	13–19		26	1	27
	19–25		19		19
	25–31		12	1	13
	31–37	1	5	1	7
	37–43	1	5	1	7
	43–49		2		2
	f	2	70	4	76

		upper rostral spines			
		6	7	8	f
rostral length (in mm)	10–14		22	5	27
	14–18	2	22	2	26
	18–22	1	11	1	13
	22–26		7	1	8
	26–30		2		2
	f	3	64	9	76

		lower rostral spines			
		2	3	4	f
rostral length (in mm)	10–14		26		26
	14–18		26	1	27
	18–22	1	10	2	13
	22–26	1	6	1	8
	26–30		2		2
	f	2	70	4	76

than the depression. The tuft grows longer with age, and the tip becomes hardly reaching to distal end of the last joint in the adult form.

The third chelipeds are somewhat variable in length, usually extending to about three-fourths of the antennal scale. But they always fall short of tip of the scale irrespective of sex and even of age, so far as the present investigation goes. The last two pereiopods usually reach far end of the basicerite in older specimens, but surmount the distal edge of the carpocerite by about the dactyli in younger ones.

As regards the present species, MILNE-EDWARDS (1837, p. 416) describes as follows:—Espêce extrêment voisine de la précédente,* mais dont le rostre ne présente en dessous que trois dents, et dont les filets des antennes supérieures sont beaucoup plus courts.

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* *Penaeus indicus.*

The specimens on which the present investigation is based well tally with the description of the abovementioned investigators.

The specimens on hand well agree with the descriptions and illustrations of *P. ashiaka* and *P. semisulcatus* given by the following investigators: KISHINOUYE; OSADA, TANIZAKI and NAKAZAWA, and YOSHIDA. Thus there is no room for doubt that the two species just mentioned above are synonymous with the present species.

Penaeus carinatus, which was erected by DANA (*op. cit.*) basing on a specimen from Singapore, is probably identical with the present species, because the flagella of "inner antennae not longer than two preceeding joints".

BATE's figure (1888) Pl. 34, Fig. 1 is in disagreement with our specimens in only point that the third cheliped is shown reaching beyond antennal scale by about three-fourths of the chela.

Our specimens are well confirmative with ALCOCK's description and figure in principal characters, but there are two points that are at variance, viz., cervical groove, according to his indications, does not reach so high, and dactylus of third maxilliped of male is slenderer and thinner.

BOONE writes in her description (*op. cit.* p. 88) "the cervical ridge above is weak and faint, vanishing less than half-way to the dorsal line", and in her figure (Pl. 22), the distance between the hepatic spine and the hepatic carina is indicated much wider. These features are, however, not in harmony with our specimens. It should be noticed again that her description of antennular flagellum does not agree with her figure; she puts (*op. cit.* p. 89) "the thickened, longer flagellum is two-thirds as long as the peduncle". But the flagellum is figured as long as the peduncle in her figure.

The present species is very intimately allied to *Penaeus semisulcatus* DE HAAN (1850, p. 191, Pl. 46, fig. 1). But it is easily separable from the latter (according to DE HAAN's figure) as given in the following Table 28.

Table 28.

Items	*P. monodon*	*P. semisulcatus*
1. Antennular flagella	more than half times as long as the peduncle	longer than (at least as long as) the peduncle
2. Third cheliped	not reaching beyond antennal seale (usually attaining about three-fifths of the scale)	reaching beyond antennal scale by about half of the chela.

Penaeus semisulcatus paucidentatus erected by PARISI (*op. cit.*) basing on a female obtained from Misaki, Sagami Bay, differs from the present species by having a spine on ventral border of rostrum instead of 2–4 on it. I am inclined to think that this is no more a case intraspecific variation.

*Penaeus bubulus** sp. nov.

(Figs. 1, *G*; 7, *B*; 15, *U B′*; 24, *K-M*; 37; 49, *C*; 53; 58, *D*; 67, *N-Q*; 73, F and *L*; 77, *P*; 113; 114).

Penaeus semisulcatus, ALCOCK, 1906, pp. 9-11, Pl. 1, fig., 2.

Penaeus carinatus, BALSS, 1914, p. 14; PARISI, 1919, p. 65; OSADA, TANIZAKI and NAKAZAWA, 1931, p. 4, Pl. 2 (lower); YU, 1935, p, 167; YOSHIDA, 1941, p. 11, fig., 4, and Pl. 2, fig., 4.

Peneus carinatus, MAKI and TSUCHIYA, 1923, pp. 31-33, Pl. 1, fig., 1.

Penaeus monodon, KISHINOUYE, 1900, pp. 7 and 15, Pl. 2, fig., 1, Pl. 7, fig., 3, and 3a; HENDERSON, 1893, p. 447.

The account given by ALCOCK is well in accord with the specimens at the writer's disposal. On the other hand, those given by KISHINOUYE and OSADA are mostly in harmony with the present specimens except that the rearmost post-rostral tooth is represented in their illustration laying at anterior one-third of carapace.

It may be mentioned in this connection that pleonic terga ar sharply carinated posterior to one-third of fourth somite as in *Penaeu monodon*, but the carina of sixth somite is somewhat higher and abruptly curves downwards in posterior about one fourth.

Mandible (Fig. 7, *B*), maxillula, first and second maxilliped closely resemble those of *Penaeus japonicus*. Maxilla belongs to Type–G_2. Third maxilliped stretching to tip of disto-lateral spine of scaphocerite. First pereiopod attains about two-fifth of antennal scale. Second one reaches to two-thirds of the scale. Third one extending beyond distal edge of the scale by about half of its palm and entire dactylus. Fourth reaching as far as distal end of carpocerite. Fifth somewhat longer than the fourth, surpassing a little beyond antennal peduncle. Dimensions and proportions of third maxilliped and all pereiopods are given in Table 29.

Appendix masculina: distal piece subelliptical in outline, about twice as long as wide, frindge with numerous setae along inner, apical and distal half of outer margin (Fig. 58, *D*).

Petasma pod-like in outline closely resembling that of *Penaeus teraoi*, without protuberance at apex of median lobe (Fig. 24, *K–M*).

Thelycum very near to that of *Penaeus monodon*, but differs as

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* This species has been known by the vernacular name "Ushi-ebi" in Japan because of its resemblance to an ox in posture and colour. Hence the specific name.

Table 29. Dimensions (in mm) of all the thoracic appendages posterior to second maxilliped and each segment from ischium to dactylus of these appendages and proportions (given in brackets) in length against dactylus.

	Total length	Ischium	Merus	Carpus	Propodus	Dactylus
Third maxilliped	65.0	15.0 (1.6)	13.2 (1.4)	12.0 (1.3)	7.0 (0.8)	9.3
First pereiopod	57.0	8.2 (0.9)	13.0 (1.3)	14.0 (1.6)	4.5 (0.5)	9.0
Second „	73.5	9.5 (1.0)	17.3 (1.9)	24.4 (2.6)	5.5 (0.6)	9.3
Third „	101.0	11.8 (1.2)	23.0 (2.3)	41.5 (4.2)	8.5 (0.9)	10.0
Fourth „	72.0	9.5 (1.1)	20.0 (2.2)	17.0 (1.9)	9.2 (1.0)	9.0
Fifth „	79.0	9.8 (1.0)	21.5 (2.3)	20.0 (2.1)	11.0 (1.2)	9.4

follows:—the apical boss of the elevation lying in front of the seminal receptacle barely longer than wide and relatively smaller, and the median lobe produced backward from the elevation larger and usually not being overlapped by both lateral lobes forming seminal receptacle (Fig. 49, *C*).

All stomodaeal ossicles similar to those of *Penaeus japonicus*. Cardiac plate, armed with 20–21 pointed spinules and zygocardiac ossicle with 11 conical teeth on inner surface (Fig. 77, *P*). Prepyloric one provided along posterior margin with 17 acuminate teeth of which median one about twice as large as submedian one (Fig. 73, *F* and *L*).

The description given above is based on a male, 182 mm long (56 mm in carapace-length), obtained from Tainan, Formosa. Other 26 males, ranging from 42.0–177.0 mm long (11.2–47.4 mm in carapace-length), and 45 females, measuring 36–235 mm long (9.9–76.0 mm in carapace-length), were examined. Besides these, 16 young specimens, 8–16 mm long, cultured in Fisheries Experimental Station of Tainan, were also placed at my disposal.

The specimens, exclusive of young ones, were obtained from Hatazawa, Chiba Pref., (1♀), Miya, Aichi Pref., (1♂, 6♀), Tainan, Formosa (24♂; 37♀), Palau (1♀), Batavia (4♀) and Menado, Celebes (1♂, 2♀), by Messrs., T. Aoki, S. Saito, N. Asano and the present author.

Distribution: Bombay, Madras, Ganjam (Henderson); Tokyo Bay and Ise Bay (Kishinouye); Hooghly delta, Mergui; Andamans, Karachi, Akyab, Madras, Pondichery, Canara, Malabar coast, Bombay, Colombo, Nagasaki, Ganjam and Orissa, Pulicat (Alcock); Yokohama (Parisi); Taityu, Tainan, Takao (Formosa) (Maki and Tsuchiya); Amoy (Yu); Singapore, Celebes, Anping and Takao (Formosa), Yokohama (Balss); Huzan (fish-market), Tyosen (Yoshida); Sashiki, Kumamoto Pref., (Osada, Tanizaki, and Nakazawa).

Note: The count of the upper rostral spines is 7 or 8 (mostly 7, 83.9%), and that of lower ones 2 or 3 (mostly 3.91%) irrespective of age and sex in larger specimens than 27.2 mm long, so far as the present investigation is concerned. But the number shows a positive correlation to the growth of the animal, and the upper spines appear earlier than the other (Fig. 114, *G–K*). The specimens, 9–11 mm long have 5 upper and no lower spines. The specimens 11.8 mm long, armed with 6 above and 2 below, and that of 15.5 mm long bears 7 above and 2 below.

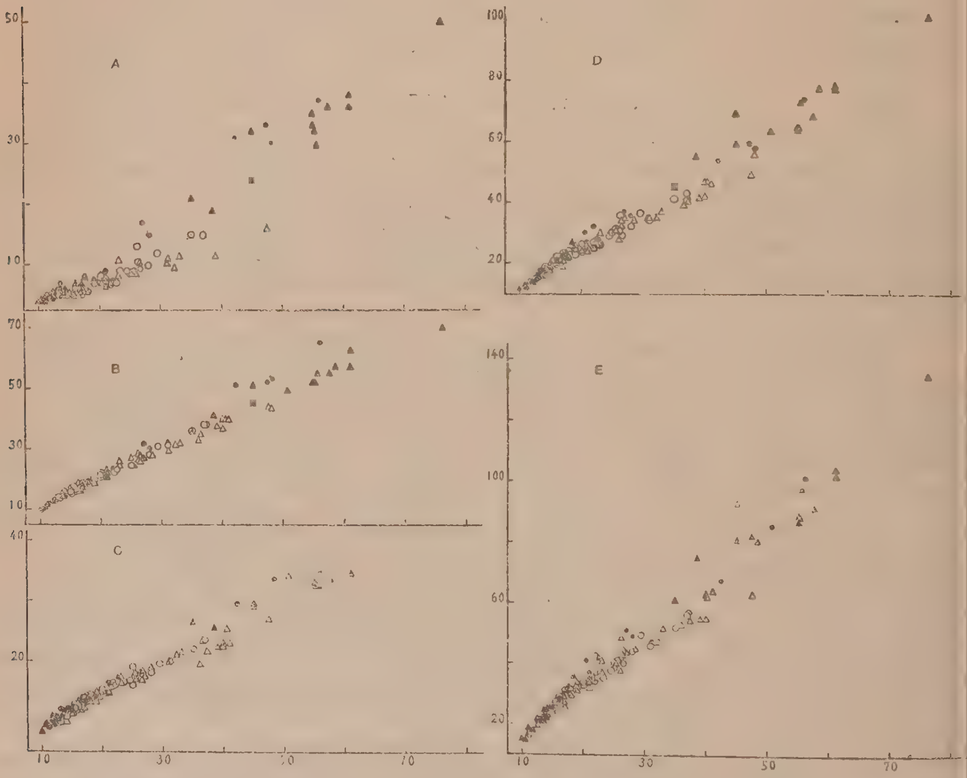

Fig. 113. Relative-growths against carapace-length of *Penaeus monodon* (soft marks) and *Penaeus bubulus* (solid marks). *A*, antennular flagellum; *B*, third maxilliped; *C*, rostrum; *D*, second pereiopod; *E*, third cheliped. Circles, male; triangles, female. Dimensions in mm.

The third maxillipeds are different in many respects with sex. In male, the appendages are longer than those of the other sex; the relative length, in relation to carapace, are linear in trend, and the proportion against carapace-length is about 1.14 (Fig. 113, *B*); propodus is furnished on distal upper border with a markedly developed protuberance which has a "pencil of hairs" reaching tip of the dactylopodite; dactylus is more or less lamellar with rounded apex as well as deeply channeled dorsal surface, and slightly longer than propodus exclusive of the protuberance (Fig. 15, *U*). In female, the relative length is linear in tendency as is the case with male, but the proportion is 0.96 (Fig. 113, *B*); both propodus and dactylus are normal in feature, and undergo but slight modification with growth (Fig. 15, *Y–Z* and *A′* and *B′*); proportions, in length, of each segment from ischium to propodus against dactylus do not display remarkable changes with advance of age (Table 30), but markedly larger on the whole than those of male.

Table 30. Proportions in length of each segment of third maxilliped of female against dactylus. B.L. and C.L., body-length and carapace-length (in brackets) in mm.

B.L and C.L.	Ischium	Merus	Carpus	Propodus
65.0 (18.4)	2.6	2.1	2.0	1.4
149.0 (44.5)	3.3	2.5	2.0	1.5
235.0 (76.0)	3.5	2.4	2.1	1.5

The metamorphosis of the distal two segments of the appendage in question of male is illustrated in Fig. 15. The "pencil of hairs" is not found yet to exist in the specimens smaller than 70.5 mm long (21.5 mm in carapace-length) (Fig. 15, *W* and *X*); the channel is observed rudimentary when the prawn reaches to 101.5 mm long (28 mm in length of carapace) (Fig. 15, *V*).

The growths in length of the antennular flagella, second and third pereiopods are proportional to that of carapace; and ratios in length to

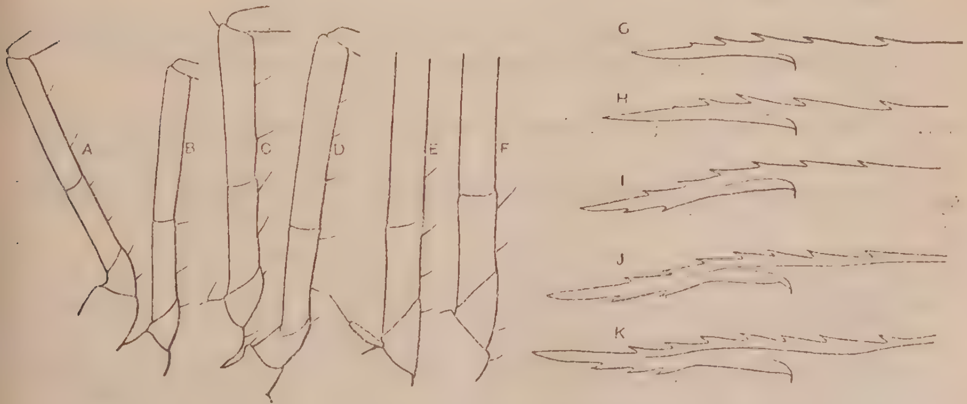

Fig. 114. Proximal four segments of fourth (*A*, *C*, and *E*) and fifth (*B*, *D*, and *F*) pereiopods, and age-variation of rostrum (*G–K*) of *Penaeus bubulus*. *A* and *B*, 5 mm in body-length except rostrum, ×55; *C* and *D*, 13.5 mm, ×50; *E* and *F*, 14.8 mm, ×35; *G*, 9 mm, ×35; *H*, 11 mm, ×35; *I*, 11.8 mm, ×20; *J*, 15.5 mm, ×10.5; *K*, 27.2 mm, ×6.

carapace are about 0.6, 1.3 and 1.7 respectively irrespective of sex (Fig. 113, *A*, *D*, and *E*). But the relative growth of the rostrum is almost linear in both sexes (Fig. 113, *C*).

In regard to exopodites of the last two pereiopods, the following fact should be noticed. The exopodites of the fourth limbs are not found to exist in 11 larval specimens, meassuring 8.5–13.5 mm in body-length (Fig. 114, *A* and *B*). But those are always observed in larger specimens than 14.8 mm long (Fig. 114, *C*). On the other hand, the exopodites of the fifth legs are found lacking in all these larval specimens. Judging from the fact given above; it seems that the exopodites of the fourth pereiopods of the present species slough off in certain post-larval stages and reappear in certain post-larval stage as in *Penaeus*

Table 31.

Items	Present species	*Penaeus monodon*
1. Adrostral carina	rather defined, reaching two-fifths of carapace	sharply defined, nearly reaching three-fifths of carapace
2. Gastro-orbital carina	occupying posterior about half the distance between post-orbital margin and base of hepatic spine	occupying posterior about two-thirds the distance between post-orbital margin and base of hepatic spine
3. Hepaic carina	horizontally straight	straight, but anteriorly inclined downwards
4. Adrostral groove	shallower	deeper
5. Distance between hepatic spine and hepatic carina	about 1/9 the length of carapace	about 1/12 the length of carapace
6. Dorsal carina of sixth pleonic somite	abruptly curves downward in subterminal portion	scarcely ourves downward in subtermimal portion
7. Antennular flagella	longer than the peduncle	shorter than the peduncle (ca. 2/3)
8. Third cheliped	surpassing apex of antennal scale	not reaching beyond apex of antennal scale
9. Fifth leg	without exopodite	with exopodite
10. Distal piece of appendix masculina	about twice as long as wide	ca. 1.3 times as long as wide
11. Median lobe of petasma	has no appendage at apex	carries an apical protuberance turning ventrally
12. Apical projection of anterior piece of thelycum	longer than wide	wider than long
13. Prepyloric ossicle	with 8 teeth on each postero-lateral margin	with 3 teeth on each postero-lateral edge

japonicus in which these slough off in post-larvae about 5.74 mm long and reappear in post-larvae about 11.5 mm long (HUDINAGA, 1942, p. 361). These of the last pereiopods are absent already at least in such larva as 8.5 mm long.

The present species is closely related to the *Penaeus monodon* FABRICIUS in general feature. But these species may be distinguished by such points as analyzed in the Table 31.

The present species is intimately allied to DE HAAN's *Penaeus semisulcatus* (1850, p. 191, Pl. 46, fig. 1), especially in the following characters:—the antennular flagella are as long as the peduncle; the hepatic carina is horizontally straight, and the distance between the carina and the hepatic spine is about one-ninth the length of carapace; the dorso-median carina of sixth pleonic somite abruptly curves downward in subterminal portion; and the third cheliped reaches beyond tip of antennal scale by about half of the chela.

But it should be mentioned that the type specimen of *Penaeus semisulcatus* DE HAAN has, according to DE MAN's reexamination (1911, p. 97, an exopodite on the fifth pereiopod. Thus it is decidedly different from the present species. Hence the erection of it as a new one.

Finally the preset species has very close resemblance to *Penaeus tahitensis* HELLER (1865, p. 121, Pl. 11, fig. 2), but greatly differs from the latter in having the following distinctions: posterior three post-rostral spines lie on carapace, the hindmost of which is inserted at anterior about two-fifths of carapace, instead of the posterior two lying on carapace and the hindmost standing at anterior one third of capapace.

Penaeus orientalis KISHINOUYE

(Figs. 1, *R*; 7, *C*; 9, *D*; 24, *Q-S*; 49, *D*; 58, *F*; 73, *M* and *S*; 77, *R*; 115; 117, *E* and *F*).

Penaeus orientalis, KISHINOUYE, 1918, p. 78; URITA, 1926, pp. 361 368, fig. *A-C*; YU, 1935, pp. 167-168; YOSHIDA, 1941, pp. 11-13, text-fig. 5, Pl. 2, fig. 2.

All the specimens at the writer's disposal stand in complete harmony with the description and figures rendered by URITA and YOSHIDA (*op. cit.*). But the following lines will supplement their accounts.

Carapace similar to that of *Penaeus bubulus* in general feature. Post-rostral carina not recognizable in posterior half of carapace. Adrostral carina becomes gradually weaker backward, reaching about two-fifths of carapace (somewhat behind the last post-rostral spine). Cervical carina rather defined in vicinity of hepatic spine only. Antennal carina also rather defined, nearly straight, arises from base of antennal spine, runs obliquely rearward, and reaches somewhat in front of hepatic spine. Gastro-orbital one as well marked as antennal carina and nearly parallel to the carina, covering about posterior three-fifths of distance between postorbital margin and base of hepatic spine. Hepatic carina hardly defined. Adrostral groove gets gradually shallower backward, and vanishing near the same position of posterior end of adrostral carina. Gastro-orbital furrow rather deep, about five times as long as wide. Cervical one narrow, straight, becomes gradually shallower upward, and attains about half-way of distance from center of carapace to hepatic spine. Hepatic sulcus narrow and shallow as in cervical one, almost horizontally straight, commencing near frontal margin of carapace and reaching to about two-sevenths of carapace (measured from post-antennal rim to posterior one). Carpocerite sexually dimorphic, much thicker in male.

Mandible similar to that of *Penaeus japonicus*: molar process flat on masticatory surface, and incisor one with two pointed teeth on cutting edge; palp attains inner base of the last joint of antennal peduncle, made up of two segments, basal one of which is short and triangular in outline, the distal rather narrow, bluntly pointed at apex, 2.5 times as long as wide, thrice the length of the basal (Fig. 7, *C*). Maxillula foliaceous consisting of two inner laciniae and an exopodite; inner distal lacinia fig-shaped in outline, somewhat larger than the other; endopodite made up of three joints, basal segment lamellar, quadruple as long as wide measured at middle, provided with a rather large protuberance near base of each anterior and posterior margin and a spinous seta at four-fifths of anterior rim, intermediate segment one-fourth the length of, and one-third the width of, the basal, but slightly thicker than the last one which is half times longer than the intermediate (Fig. 9, *D*). Endopodite of first maxilliped is segmented into five, proportions in length against the last joint: first 1.1, second 0.3, third 0.4, and fourth 0.6. Second maxilliped seven-jointed, inverted J-shaped as usual, meropodite depressed and subrectangular in outline, twice as long as wide, somewhat lamellar on inner half. Third pediform, reaching a little beyond tip of antennular peduncle in male, reaching to midway of second antennular segment in female. First cheliped extends to far end of carpocerite. Second reaches to or beyond distal edge of first antennular segment. Third stretching as far as antennal scale.

Proportions in length of each segment from ischium to propodus of third maxilliped and all pereiopods are given in Table 32.

Appendix masculina: Distal piece spatulate with broadly rounded apex, fringed with thickly set rather short setae along inner, outer and distal edges, about 1.2 times as long as wide (Fig. 58, *F*).

Petasma: median lobe bluntly pointed at apex and somewhat sur-

Table 32.

Items		Ischium	Merus	Carpus	Propodus
Third maxilliped	♂	1.56	1.25	1.37	0.95
	♀	3.92	2.82	2.56	1.74
First pereiopod	♂	1.00	1.62	1.55	0.58
	♀	0.95	1.56	1.57	0.53
Second ,,	♂	1.15	2.15	2.92	0.74
	♀	1.13	2.13	2.80	0.60
Third ,,	♂	1.27	2.73	4.21	0.98
	♀	1.19	2.60	4.03	0.88
Fourth ,,	♂	1.11	2.56	2.13	1.41
	♀	1.00	1.85	1.93	1.35
Fifth ,,	♂	1.02	2.10	2.27	1.40
	♀	1.00	2.00	2.31	1.38

passing distal margin of lateral lobe; lateral lobe armed on outer surface with numerous stout setae arranged in a longitudinal series in distal half. (Fig. 24, *Q–S*).

Thelycum consists of anterior and posterior pieces as in that of *Penaeus monodon* and *Penaeus bubulus.* Anterior piece anteriorly has a well-calcified boss with rounded apex pointing forward, and posteriorly ill-calcified three lobes directed backwards, median one of which is free and pointed, reaching about a third of seminal receptacle, but lateral one firmly attached on sternite of the last thoracic somite. Posterior piece forms a seminal receptacle which is ovoid in outline, a little longer than wide, consisting of two lateral lobes, each of which is provided with straight median margin recurving ventrally and meeting each other, minutely notched at posterior one-third of outer margin, and overlaps postero-lateral lobe of anterior piece (Fig. 49, *D*).

Cardiac plate and zygocardiac ossicle very similar to those of *Penaeus teraoi,* the former armed with acute spinules set in a row running longitudinally straight, and the latter with a curved longitudinal series made up of about 11 conical teeth, the first one of which is much larger than the rest (Fig. 77, *R*). Cardiac, pterocardiac and prezygocardiac ossicles closely resemble those of *Penaeus japonicus.* Urocardiac rounded on anterior margin, furnished with a pair of remarkably developed acuminate processes on lateral margins near anterior end (Fig. 73, *M*). Prepyloric bearing about eight pointed teeth along each postero-lateral edge (Fig. 73, *M* and *S*).

The description given above is based on a male, 152.5 mm (45.0 mm in carapace-length), and a female, 183.0 mm long (55.0 mm) abtained from Tokyo fish market. Besides, 8 males, 96.5–154.0 mm long (26.5–41.7 mm), and 15 females, 138.0–159.0 mm (45.5–56.0 mm) were examined. These were secured from Chusan Islands, China (2♂) by Dr. I. TOMIYAMA and Mr. J. OZAKI, and from Tokyo fish market (6♂, 15♀).

Distribution: Lung-kao Chefoo, Tangkon, Tsingtao, Gheffoo (YU). Chingwantas; Chin-chau, Lung-Kao; Chefoo; Shintao, near Tsingtao (URITA).

Note: In regard to the rostrum, no sexual difference is observable (Fig. 115, *C*). Ratio of it in length to carapace is variable within a limit from 0.68 to 1.03, but mostly 0.8. Unarmed portion of the upper border ranges from 30% to 50% (mostly 40%) of the length. The dorsal carina armed with 7–9, usually 8 teeth, posterior 3 of which are found always on carapace, whilst, the ventral carina bears 3–5, usually 4 teeth.

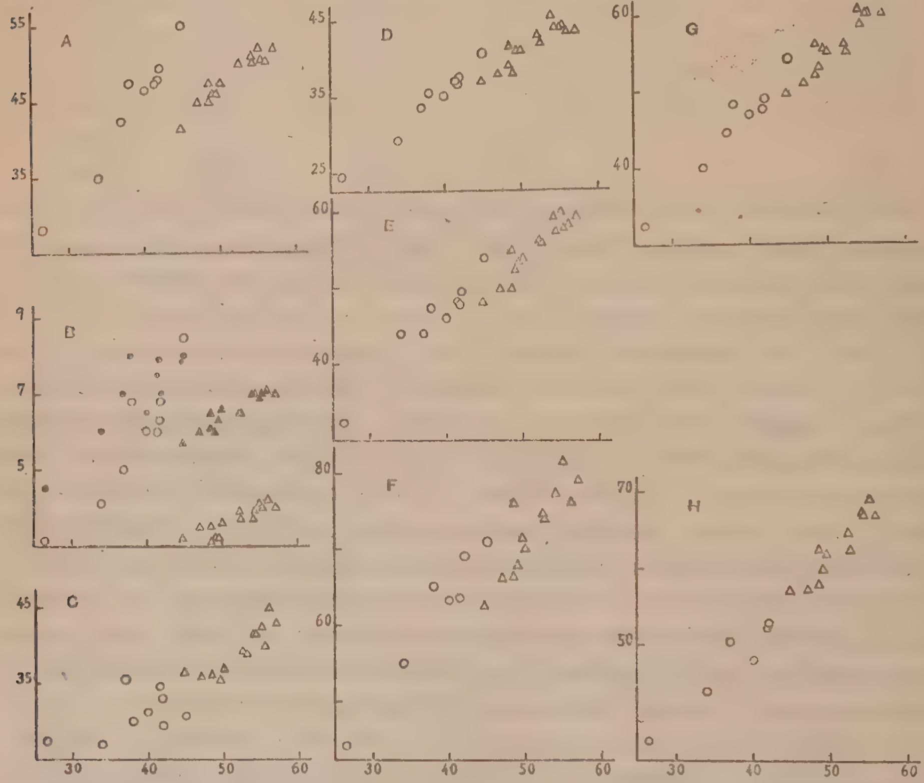

Fig. 115. Relative growths, in length, of third maxilliped (*A*), propodus (solid marks) and dactylus (soft marks) of the same appendage (*B*), rostrum (*C*), first pereiopod (*D*), second one (*E*), third one (*F*), fourth one (*G*), and fifth one (*H*) of *Penaeus orientalis* in relation to carapace (dimension in mm). Circles, male; triangles, female.

The third maxillipeds exhibit remarkable secondary sexual differences, but the relative growths in length against the carapace are isogonic in both sexes. In male, it is about 1.2 times as long as carapace; the propodus is provided on the distal upper edge with a well developed protuberance which bears a tuft of apical hairs nearly reaching tip of the dactylus, and the dactylopodite is somewhat lamellar, longitudinally channeled on dorsal surface, (Fig. 117, *E*), ranging from 0.6 to 1.1 times as long as propodus (excluding the protuberance); the relative growths of the last two joints, as referred to carapace-length, are much larger than those of female. In female, the appendage is about 0.9 times the length of the carapace (Fig. 117, *F*), the distal two joints are normal in general aspect, and the dactylus is 0.5–0.6 times as long as the propodus (Fig. 115, *A* and *B*).

The first to fifth pereiopods demonstrate no sexual variation, and the growth, in length, of these limbs are proportional to that of the carapace (Fig. 115, *D–H*). The ratios of leg-length to carapace-length are as follows:—first leg 0.7–0.9, second 1.0–1.2, third 1.4–1.7, fourth 1.0–1.3, and fifth 1.2–1.4.

The present species is very near to *Penaeus indicus longirostris* De Man (1911, pp. 103–104) and *Penaeus indicus* H. Milne-Edwards but it is differentiated from the former by having the following features, viz., the rostrum reaches to or beyond tip of the antennal scale, instead of surpassing the scale by a third to two-fifths of its length; the lower rostral spine 3–5 in number; and postrostral carina vanishing in posterior about half of carapace, and not furnished with 2 or 3 shallow pits, and separable from the latter as given below (Table 33):—

Table 33.

Items	present species	*Penaeus indicus*
1. Post-rostral carina	barely convex in profile, not recognizable backward to midway of carapace	considerably elevated, somewhat trnangular in profile
2. Hepatic groove	ill-defined	absent at all
3. Endopodite of maxillula	three-segmented	two-segmented
4. Third pereiopod	reaching tip of antennal scale	surpassing tip of antennal scale by about half of chela
5. Median lobe of petasma	bluntly pointed at apex, extending considerably beyond distal margin of lateral lobe	rounded at apex, reaching as far as distal edge of lateral lobe
6. Distal piece of ap-appendix masculina	subrectangular in outline, ca. 1.4 times as long as wide	deltoid with rounded apex, ca. 1.1 times as long as wide

Penaeus penicillatus ALCOCK

(Figs. 7, *J*; 13, *E* and *F*; 20, *I*; 24, *T–V*; 49, *E*; 58, *H*; 73, *P* and *V*; 77, *U*; 116; 117, *B*).

Peneus penicillatus, ALCOCK, 1905, p. 525; 1906, p. 13, Pl. 2, fig. 5; SCHMITT, 1926, p. 361.

Penaeus penicillatus, OO, 1937, pp. 62-66, figs. *A–E*.

Rostrum almost horizontally straight, a little surpassing tip of antennal scale, armed with 7 teeth above (posterior 3 on carapace, the last one at ca. two-fifths of carapace), and 5 ones below in distal half. Post-rostral crest considerably convex, highest at one sixth of carapace, reaching about six-sevenths of carapace. Adrostral carina gets gradually weaker backward, and fades away a little behind the last post-rostral spine. Gastro-orbital and antennal carinae rather defined, the former occupies posterior two-thirds of the distance between post-orbital margin and hepatic spine. Cervical carina short but straight, rather sharply defined, reaching about a quarter the distance from hepatic spine to center of carapace. Hepatic absent at all. Cervical groove narrow, attains midway toward center of carapace, upper half hardly defined and more or less curved dorsally. Supra-orbital and pterygostomian angles rounded. Antennal and hepatic spines small, subequal in size. Abdomen dorsally carinated backward to third segment, the carina of sixth somite suddenly slopes down in subterminal portion and ends in an acute spinule pointing backwards; sixth somite has no minute spine near postero-inferior angles. Telson tapering into a sharply pointed tip, with a well-defined dorso-median groove, unarmed along dorso-lateral margins, about three times as long as wide measured at base.

Stylocerite attains middle of first antennular segment. Mandible similar to that of *Penaeus japonicus*, but the notch of incisor process not conspicuous; the last segment of palp broad, bluntly pointed at apex, remarkably excavated on disto-lateral edge, twice as long as wide, thrice the length of the basal (Fig. 7, *J*). Maxillulary palp two-jointed; basal joint lamellar, more or less distally narrowed, 2.5 times as long as wide measured at base, anterior border wavy, provided with a long spinous seta at two-sevenths, and the posterior gently curves forwards; the second one-sixth the width of the basal measured at base, bluntly pointed at apex, a quarter the length of the first joint. Maxilla belongs to Type-G_2 (Fig. 117, *B*). First maxilliped with palp segmented into five. Third maxilliped reaching to far end of second article of antennular peduncle in male, and to distal end of basal article of the peduncle in female, proportions in length to dactylus: ischium 1.5, merus 1.3, carpus 1.1, and propodus 0.7 in male, whilst ischium 3.1, merus 2.3, carpus 2.1, and propodus 1.3 in female; propodus has a " pencil of hairs " on distal upper edge; dactylus lamellar, deeply channeled on dorsal surface (Fig. 13, *E* and *F*). First and the last two pereiopods attain about middle of antennal scale. Second reaching distal edge of second antennular segment. Third extends beyond tip of antennal scale by half of chela. Dimensions of all pereiopods and each of distal five segments of these legs, and proportions of each segment from ischium to propodus of all the legs in length to dactylus given in Table 34.

Table 34. Dimensions (in mm) and the proportions (in brackets) of *Penaeus penicillatus* of a male, 112 mm long and a female, 126 mm, long, obtained from Tainan, Formosa.

Items	Sex	Total length	Ischium	Merus	Carpus	Propodus	Dactylus
1. First leg	♂	34.0	5.0 (1.02)	8.1 (1.65)	9.5 (1.93)	2.0 (0.59)	4.9
	♀	33.0	5.0 (1.00)	8.2 (1.64)	9.5 (1.90)	3.0 (0.60)	5.0
2. Second leg	♂	43.0	5.0 (0.98)	11.0 (2.15)	16.3 (3.19)	3.4 (0.66)	5.1
	♀	43.0	6.0 (1.20)	11.4 (2.28)	16.8 (3.36)	3.5 (0.70)	5.0
3. Third leg	♂	59.0	6.0 (1.09)	15.0 (2.72)	24.5 (4.45)	5.0 (0.90)	5.5
	♀	61.0	6.6 (1.22)	1.54 (2.85)	25.0 (4.62)	5.0 (0.92)	5.4
4. Fourth leg	♂	43.5	4.5 (0.81)	12.0 (2.18)	9.6 (1.74)	8.0 (1.45)	5.5
	♀	43.0	5.0 (1.00)	12.5 (2.50)	10.0 (2.00)	8.5 (1.70)	5.4
5. Fifth leg	♂	46.2	5.0 (0.76)	13.0 (2.00)	12.0 (1.84)	8.2 (1.26)	6.5
	♀	48.2	5.2 (0.80)	13.5 (2.07)	12.5 (1.92)	9.0 (1.38)	6.5

Appendix masculina: distal scale spatulate, distally somewhat narrowed, rounded at apex, fringed with short setae, about a third longer than the gratest width (Fig. 58, *H*).

Petasma spout-like, resembles that of *Penaeus teraoi* (Fig. 24, *T* and *U*); median lobe ends in a protuberance extending as far as distal margin of lateral lobe (Fig. 24, *V*); lateral lobe with sparsely set five setae on outer surface, distal edge serrated with many stout spinules in subterminal portion.

Thelycum: apical boss of anterior piece ovoid in outline, minutely pointed at apex, a little longer than wide, about two-ninths as wide as seminal receptacle which is almost circular in outline (Fig. 49, *E*).

Cardiac plate armed with about 26 spinules (Fig. 77, *U*). Cardiac, pterocardiac and prezygocardiac ossicles closely resemble those of *Penaeus japonicus*. Zygocardiac has 8–10 conical teeth, of which the foremost one is much larger than other ones which are subequal in size (Fig. 77, *U*). Prepyloric furnished on each postero-lateral margin with 8–10 pointed teeth which get gradually larger in size as they approach toward tip (Fig. 73, *P* and *V*).

Young: Postrostral crest almost horizontal in profile. Abdomen dorsally carinated backward to fourth segment. Third maxilliped hardly reaching to distal end of basal segment of antennular peduncle; propodus and dactylus do not yet exhibit secondary sexual character at all, the former about 1.3 times as long as the latter. Petasmal endopodites still not united with each other.

The foregoing description is founded upon a male, 122.0 mm long (30.6 mm in carapace-length), a female, 126.0 mm long (32.7 mm), and young male, 71.6 mm long (18.4 mm), all of which were secured from Tainan, Formosa. In addition to these, three males, 89.4–100.0 mm long (22.5–25.5 mm), and three females, 66.4–107.5 mm long (17.5–28.0 mm) were also examined.

Locality: Tainan, Formosa (2♂, 2♀, by Oo-U-Kijo; Surabaya (3♂, 2♀), by S. SAITÔ.

Distribution: Mergui, Orissa, Karachi, Bombay (ALCOCK); Tainan (Oo).

Note: The upper and lower rostral spines are rather variable in number. The upper ones 7 or 8, posterior 3 of which are always found on carapace. Of nine specimens, five have 8 and four have 7. The lower ones range from 4 to 6, and mostly 5.

As regards third maxilliped, the ratio of dactylus-length to propodus-length varies 0.68 to 0.83 in males smaller than 100 mm long (25.5 mm in carapace-length), but it is 1.51 in the largest male (122 mm long) dealt with. Thus it may be argued that the dactylus of male rapidly lengthens at least during the period measuring from 100 mm to 122 mm long. On the other hand, it seems that the ratio in female does not display marked age-variation. In four of the present specimens, 66.4–126.0 mm long, it ranges 0.75 to 0.87 (Fig. 116).

The specimens dealt with herein well agree with ALCOCK's (*op. cit.*) description of *Penaeus indicus penicillatus*, but are in discrepancy with his figure, in the following respect only: the third maxilliped does not surpass tip of antennular peduncle instead of reaching beyond the tip by half of its dactylus. However, such disagreement is perhaps due to difference of age.

Penaeus merguiensis DE MAN

(Figs. 7, *L*; 20, *G*; 25, *A C*; 49, *F*; 58, *K*; 73, *O* and *U*; 77, *V*; 116; 117, *A*, *G*, and *H*).

Penaeus merguiensis, DE MAN, 1888, pp. 287-290, Pl. 18, fig. 8.

Peneus merguiensis, SCHMITT, 1926 p. 260; BOONE, 1935, pp. 96-101, text-fig. 7, Pl. 24.

Penaeus indicus merguiensis, ALCOCK, 1905, p. 515; 1906, p. 13, Pl. 2, fig. 4; RATHBUN, 1908-10, p. 351.

Penaeus indicus, BATE, 1888, p. 248, Pl. 33, fig. 2; DE MAN, 1892, p. 511; HENDERSON, 1893, p. 447.

Mandibular palp two-segmented; the last joint subrhomic, bluntly pointed at apex, about twice as long as wide, thrice as long as and two times as wide as basal joint (Fig. 7, *L*). Endopodite of maxillula segmented into two, first article quadruple as long as second one (Fig. 117, *A*). Third maxilliped (Fig. 117, *G* and *H*) reaching half-way of intermediate article of antennular peduncle. First, fourth and fifth pereiopods reach to or beyond distal margin of first segment of antennular peduncle. Second limb extending tip of antennular peduncle. Third one surmounts far end of antennal scale by entire chela. Dimensions and ratios of each segment from ischium to propodus against dactylus of all thoracic appendages backward to second maxilliped are given in Table 35.

Table 35. Dimension in mm; ratios in brackets. Max; maxilliped; T L, total length.

Items	Sex	TL.	Ischium	Merus	Carpus	Propodus	Dactylus
Third max.	♂	25.5	6.4 (2.46)	6.4 (2.46)	6.2 (2.38)	4.2 (1.61)	2.6
	♀	28.0	7.0 (3.33)	6.4 (3.04)	6.0 (2.85)	3.9 (1.85)	2.1
First leg	♂	24.0	3.5 (1.00)	6.5 (1.85)	7.5 (2.14)	2.5 (0.71)	3.5
	♀	29.0	4.2 (1.05)	7.8 (1.95)	8.0 (2.00)	2.5 (0.67)	4.0
Second leg	♂	32.5	3.5 (0.94)	8.5 (2.29)	12.8 (3.45)	2.5 (0.67)	3.7
	♀	39.0	4.4 (1.10)	10.0 (2.50)	14.5 (3.62)	3.2 (0.80)	4.0
Third leg	♂	45.0	4.0 (1.14)	12.0 (3.42)	20.5 (5.85)	3.8 (1.08)	3.5
	♀	53.0	5.4 (1.13)	13.5 (3.37)	23.3 (5.82)	4.7 (1.18)	4.0
Fourth leg		—	—	—	—	—	—
	♀	37.8	4.0 (0.95)	11.0 (2.61)	8.5 (2.02)	7.5 (1.78)	4.2
Fifth leg		—	—	—	—	—	—
	♀	39.3	4.5 (1.00)	11.0 (2.44)	10.0 (2.22)	7.0 (1.55)	4.5

Appendix masculina closely related to that of *Penaeus penicillatus*; distal scale about 1.3 times as long as wide measured in the broadest region (Fig. 58, *K*).

Petasma closely resembles that of *Penaeus penicillatus* in general configuration (Fig. 25, *A–C*); median margin rounded at apex, extending as far as distal margin of lateral lobe.

Thelycum also resembles that of *Penaeus penicillatus* (Fig. 49, *F*); apical projection of anterior piece as long as wide, about two-sevenths as wide as seminal receptacle which is circular in outline.

Cardiac plate armed with 23–26 spinules equidistantly set in a longitudinal series (Fig. 77, *V*). Zygocardiac ossicle provided with rather closely set 8–10 conical teeth arranged in a longitudinal row, the foremost tooth much larger than others which become gradually smaller backward. Urocardiac and prepyloric ossicles very similar to those of *Penaeus penicillatus*, the latter with about eight sharply pointed teeth on each postero-lateral margin (Fig. 73, *O* and *U*).

The abovementioned description is based on a male, 74.0 mm long (19.8 mm in carapace-length) collected from Macassar, and a female, 100.5 mm long (25.4 mm) from Batavia. Besides, six females, 88.5–97.0 mm long (21.5–24.5 mm), obtained from Macassar, Batavia and Singapore by Messrs., Y. HIBI and I. MATSUI were also examined.

Distribution: Philippine Island (BATE); Bay of Bima; Makassar, West coast of New Guinea, Java Sea, Mergui (DE MAN); Karachi, Bombay, Palk Strait, Orissa and Ganjam, Hooghly Delta (ALCOCK); Lower Siam (KEMP).

Note: The number of the upper rostral spines is 7 or 8, posterior 3 of which are inserted on carapace without exception. Of eight specimens, five have 1 and the rest is provided with 8 spines. That of the lower ones is 4 or 5. Among those specimens, six have 4 and two have 5.

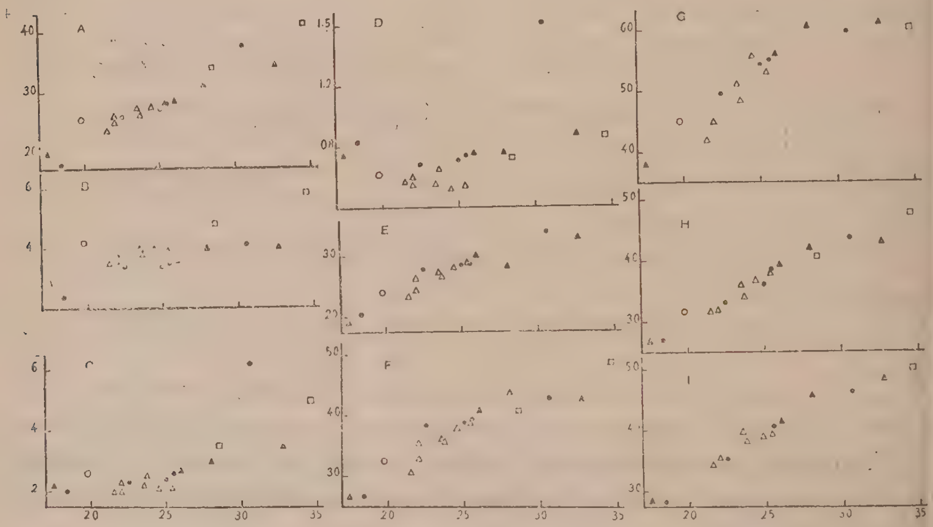

Fig. 116. Lengths (in mm) of third maxilliped (*A*), propodus of third maxilliped (*B*), dactylus of the same appendage (*C*), first leg (*E*), second one (*F*), third one (*G*), fourth one (*H*), fifth one (*I*), and ratio in length of dactylus to propodus of third maxilliped (*D*) in relation to carapace-length. Circles, male; triangles, female; square, male of *Penaeus indicus*. Solid marks, *Penaeus penicillatus*; soft ones, *Penaeus merguiensis*.

Remarkably enough, the mid-dorsal carina of the fourth pleoni somite appears to be different by age. It is observed rather defined in a female, 100.5 mm long, hardly recognizable in those specimens, 88.5–97.0 mm long, whilst it is not found to exist in a male, 74 mm long.

As to the third maxilliped, the dactylus is much shorter than th propodus. The proportions in length of dactylus against propodus rang 0.52 to 0.65 (Fig. 116, *B–D*).

The specimens at the author's disposal well correspond to the descriptions and figures of BATE, DE MAN, ALCOCK and BOONE. except that the illustration given by BOONE (*op. cit.*, Pl. 24), in which the upper antennular flagellum is figured as much shorter than the peduncle.

The present species is closely allied to *Penaeus penicillatus* in general configuration. However, the former may be distinguished from the latter as given in the annexed table (Table 36).

Table 36.

Items	present species	*Penaeus penicillatus*
1. Post-rostral carina	prominent, triangular in profile	rather prominent, convex in profile
2. Third maxilliped	dactylus 0.52–0.65 times as long as propodus	dactylus 0.68–1.51 times as long as propodus
3. Apical boss of anterior piece of thelycum	as long as wide, about two-sevenths as wide as seminal receptacle	longer than wide, about two-ninths as wide as seminal receptacle

Finally it should be noticed in this place that the lengths of pereiopods are not important at all for discrimination of the present species from *Penaeus penicillatus* (Fig. 116, *E–I*).

Penaeus indicus H. MILNE-EDWARDS

(Figs. 7, *K*; 20, *H*; 24, *W–Z*; 58, *J*; 73, N, and *T*; 77, *T*; 116; 117, *I*)

Penaeus indicus, H. MILNE-EDWARDS, 1837, p. 45; DANA, 1852, p. 604; HELLER, 1865, p. 122; MIERS, 1878, p. 301; LANCHESTER, 1900, p. 474; ALCOCK, 1906, p. 12, Pl, 1, fig. 3; YU, 1935, p. 168; BLANCO, 1937, p. 224, Pl. 2, figs. 6 and 7.

Peneus indicus, BOONE, 1935, p. 91, text-fig. 6, Pl. 23; SCHMITT, 1926, p. 360.

Mouth-parts closely resemble those of *Penaeus merguiensis* (Figs, 7, *K* and 117, *I*).

Table 37. Dimensions in mm; ratios in bracket; max., maxilliped; TL, total-length.

Items	TL	Ischium	Merus	Carpus	Propodus	Dactylus
3rd max.	41.0	11.5 (2.75)	8.5 (1.70)	7.8 (1.56)	4.8 (0.96)	5.0
1st leg.	36.1	5.1 (1.02)	9.5 (1.90)	10.8 (2.16)	3.0 (0.60)	5.0
2nd „	49.0	6.0 (1.11)	12.6 (2.33)	18.0 (3.33)	3.8 (0.70)	5.4
3rd „	54.0	7.0 (1.16)	16.2 (2.70)	28.0 (4.50)	5.9 (0.98)	6.0
4th „	47.5	5.6 (0.98)	13.5 (2.36)	10.5 (1.84)	8.5 (1.49)	5.7
5th „	50.0	6.0 (0.85)	14.0 (2.00)	13.0 (1.85)	9.0 (1.28)	7.0

Third maxilliped reaches to distal end of second segment of antennular peduncle. First, fourth and fifth pereiopods attain about middl of antennal scale, the third extends beyond tip of the scale by abou half of chela.

Dimensions and ratios of each segment from ischium to propodus o third maxilliped and all pereiopods against dactylus are given in Table 37.

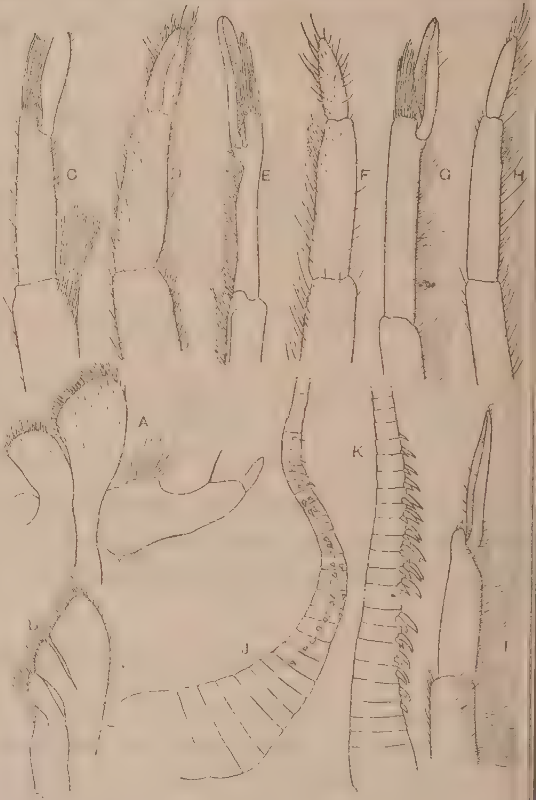

Fig. 117. Maxillula (*A*), inner four strips of maxilla (*B*), distal portion of third maxilliped (*C–I*), and basal portion of antennular flagellum (*J* and *K*). *A*, *Penaeus merguiensis*, 100.5 mm in body-length (25.4 mm in carapace-length), × 7.5; *B*, *Penaeus penicillatus*, 122 (30.6), × 6; *C*, *Penaeus esculentus*, male, 129 (33.2), ×4; *D*, *P. esculentus*, female, 135.5 (35), × 4; *E*, *Penaeus orientalis*, male, 146 (41.5), ×3; *F*, *P. orientalis*, female, 177 (52.5), ×3.5; *G*, *Penaeus merguiensis*, male, 74 (19.8), ×7.5; *H*, *P. merguiensis*, female, 89 (22), ×7.5; *I*, *Penaeus indicus*, male, 135 (34.5), ×3.5; *J*, *Penaeus vannamei*, male, 138 (35.5) ×10.5; *K*, *Penaeus stylirostris*, male, 147 (41), ×7.5.

Appendix masculina: distal piece deltoid in outline, with rounded apex, fringed with thickly set setae, about 1.1 times as long as wide measured in the widest region (Fig. 58, *J*).

Petasma: median lobe rounded at tip, projecting as far forward as broadly rounded apex of lateral lobe; lateral lobe covered with sparsely set fine setae on outer surface, terminal portion of distal margin serrated with about 12 well calcified teeth which become gradually smaller toward tip (Fig. 24, *W–Z*).

Cardiac plate and Zygocardiac ossicle similar to those of *Penaeus merguiensis* in general aspect, but the former has 28–30 equidistant spinules set in a longitudinal row, and the latter bearing about 11 conical teeth which are set in an arc-shaped series (Fig. 77, *T*). Urocardiac and prepyloric ones also intimately related to those of *Penaeus merguiensis*, the latter armed with about ten pointed teeth which get successively larger as they approach toward tip (Fig. 73, *N* and *T*).

Two males, 135 mm and 120 mm long (34.6 mm and 28.5 mm in carapace-length respectively), obtained from Bangkok by Mr. I. Matsui were examined. The above mentioned description is based on the former.

Distribution: Coromandel (Milne-Edwards); Singapore (Dana); all coast of India, Ceylon, Andamans, Singapore (Alcock); Singapore (Boone); Amoy (Yu); Manila, Malolos, Santa Cruz (Philippines) (Blanco).

Note: Remarkably enough, the tuft of hairs of the propodus of third maxilliped is found very rudimentarily in both our specimens (Fig. 117, *I*). But it is probably an abnormal condition. Our specimens agree with descriptions and illustrations of H. Milne-Edwards, Alcock, Boone, and Blanco, except the figures given by Alcock and Boone. In Alcock's and Boone's figures, all the pereiopods are represented somewhat shorter. For instance, the third pereiopods are drawn reaching a little behind tip of antennal scale. But the pereiopods of the specimens dealt with stretch beyond distal edge of the scale by about half of the chela.

The descriptions of *Penaeus indicus* given by Miers (*op. cit.*) are too brief to justify their identification. The present species is very closely related to *Penaeus merguiensis* in general aspects. But they are separable by such points given in Table 38.

Table 38.

Items	Present species	*Penaeus merguiensis*
1. Gastro-orbital carina.	rather sharply defined	bluntly defined
2. Dactylus of third maxilliped of adult male	as long as propodus	about half as long as propodus
3. Third pereiopod	reaching beyond tip of scaphocerite by about half of chela	extending beyond tip of scaphocerite by about entire chela

However, the demarkation of these two allied forms is still by no means satisfactory. Therefore, it is hoped that a statistical study on the basis of a large number of specimens will clear up the distinct characters.

Penaeus vannamei Boone

(Figs. 7, *I*; 26, *D-F*; 47, *V*; 58, *M*; 74, *B* and *H*; 78, *C*; 117, *J*)

Penaeus vannanei, Boone, 1931; Burkenroad, 1934a, p. 87.

Amtennular flagella different in length; upper flagellum as long as basal antennular segment, markedly expanded in proximal half and filiform in the rest; lower one shorter than the other, a little longer than distal two joints of antennular peduncle, armed with sparsely set short setae on upper surface of proximal half (Fig. 117, *J*). Mandibular palp resembles that of *Penaeus monodon;* distal segment somewhat less than twice as long as wide, and about three times the length of basal one (Fig. 7, *I*). Maxillulary palp 3-segmented. Maxilla is of Type–G_3. Endopodite of first maxilliped segmented into five. Second maxilliped seven-segmented; meropodite subrectangular in outline, about 2.4 times as long as wide, somewhat lamellar in inner half; carpus and propodus subequal in length, about half the length of merus; dactylus about 0.7 times the length of merus. Third maxilliped reaches a little beyond distal margin of basal segment of antennular peduncle; ischium about twice the length of dactylus; merus equals to carpus in size, 0.4–0.7 times longer than dactylus.

First and fourth pereiopods hardly extend to tip of stylocerite Second attains about middle of basal antennular segment. Third stre ches to tip of antennal scale; proportions in length to dactylus: ischium 1.6, merus 2.9, carpus 4.9, and propodus 1. Fifth reaches beyon tip of stylocerite by half of dactylus; proportion in length to dactylus ischium 1.5, merus and carpus 2.5, and propodus, 1.6.

Appendix masculina: distal piece spatulate in shape, rounded o distal margin, about twice as long as wide, a little shorter than prox mal piece, provided at one-third of outer margin with a knob bearin thickly set rather long setae; inner margin fringed with long setae i distal half (Fig. 58, *M*).

Petasma is of Type–M_4 median lobe truncate at apex, lateral on pointed at tip which remarkably surpasses distal border of median lob (Fig. 26, *D–F*).

Thelycum: a conspicuous concavo-convex projection with conve surface forward is present on sternite between fourth thoracic legs. pair of upstanding transverse plates directed antero-laterally are situate at about middle of the last thoracic sternite (Fig. 47, *V*). Cardiac pla armed with about 35 subequidistant minute teeth which are longitudin ly alined as in those of other species of *Penaeus* (Fig. 78, *C*).

Zygocardiac is of Type–R_1, provided with about 29 closely set tee which are transversely compressed, wider than long, abruptly pointed a apex, yellowish brown in alcoholic specimen as given elswhere (Fig. 7 *C*). Prepyloric ossicle has 14–16 pointed teeth along each postero-later edge (Fig. 74, *B* and *H*).

The foregoing description is mostly made upon a male, 140 m long (34.6 mm in carapace-length). Besides, a female, 159 mm long (41 mm), on which the description of thelycum is based, was also examined.

Habitat: Gulf of California (27° 06′ *N.*; 110° 10′ *W*), depth 45 fathoms. Bottom, mud. Water-temperature, 27.5° *C.*

Distribution: Pacific coast of America from Mexico to Panama.

Note: The rostrum is similar to that of *Penaeus japonicus* series in shape, armed with 8 or 9 teeth above, posterior 4 of which are placed on carapace, and has 2 ones on the inferior border.

The carapace very similar to that of *Penaeus stylirostris*, but only difference is that the adrostral carina of the present species attains just lateral to the epigastric spine as is the case with that of *Penaeus esculentus.*

The lower antennular flagellum undergoes somewhat sexual variation. That of male is furnished with many short setae as in the flagellum of *Penaeus stylirostris*, though the armatures of the present species are less in number and much smaller in size than those of *P. stylirostris.* The third maxillipeds are not remarkable in sexual modification, even in length. As to the pereiopods of female, the posterior three pairs of them somewhat shorter than those of male: the third ones reach to tip of the antennular peduncle; and those of the fourth and fifth attain far end of the carpocerite.

A couple of specimens at the author's disposal well tally with the description of the present species given by BURKENROAD (*op. cit.*) although the original description was not available for the writer.

The present species closely related to *Penaeus stylirostris* STIMPSON, but they are easily discriminated from each other on the basis of the features of adrostral carina, antennular flagella, appendix masculina, copulatory organs, number of spinules found on cardiac plate, teeth of zygocardiac ossicle and prepylaric one.

Penaeus esculentus HASWELL

(Figs. 7, *M*; 20, *E*; 25, *G-I*; 49, *G*; 58, *I*; 73, *Q* and *W*; 78, *A*; 117, *C* and *D*).

Penaeus esculentus HASWELL, 1879, p. 38.

Peneus esculentus, SCHMITT, 1926, pp. 362-365, Pl. 64, figs. 1-4.

Sixth pleonic somite armed with a minute but stout spine directed postero-ventrally at postero-lateral angle.

Mandible: molar process almost flat on masticatory surface, with sharply defined and somewhat projected postero-median edge. Incisor one provided with rather sharp cutting edge which is minutly notched at two-thirds as in *Penaeus japonicus.* Palp foliaceous, two-segmented, reaching to base of the last antennal segment; distal segment broad, bluntly pointed at apex, remarkably excavated on distal outer margin, about four-fifths longer than the greatest breadth, and thrice the length of basal joint (Fig. 7, *M*). Endopodite of maxillula segmented into three, and that of first maxilliped five-segmented. Third maxilliped reaches to far end of first antennular segment; propodus considerably produced on distal upper edge into a knob which has a tuft of thickly set long apical hairs reaching a little beyond tip of dactylus, the last segment longitudinally excavated on dorsal surface, rounded at apex, about 0.67 times the length of propodus (excluding knob) in male; but propodus lacking both knob and tuft of hairs, and dactylus furnished with shallow and narrow longitudinal depression on upper surface and about 0.57 times as long as propodus in female (Fig. 117, *C* and *D*).

First, fourth and fifth pereiopods extend to tip of stylocerite. Second reaches as far as third maxilliped. Third reaches to or beyond distal end of intermediate antennular segment.

With regard to all thoracic appendages posterior to second maxilliped, dimensions and proportions of each segment from ischium to propodus in length against dactylus are given in Table 39.

Table 39. Dimensions in mm; proportions in length to dactylus (in brackets). max., maxilliped; TL, total length.

Items	Sex	TL	Ischium	Merus	Carpus	Propodus	Dactylus
Third max.	♂	33.0	8.5 (2.42)	7.5 (2.14)	6.4 (1.82)	5.2 (1.48)	3.5
	♀	35.5	9.6 (3.20)	7.8 (2.60)	6.9 (2.30)	5.3 (1.76)	3.0
First leg	♂	29.0	5.0 (1.04)	7.0 (1.45)	7.6 (1.58)	2.5 (0.52)	4.8
	♀	31.2	5.5 (1.10)	7.4 (1.48)	8.0 (1.60)	3.0 (0.60)	5.0
Second leg	♂	38.3	5.5 (1.10)	9.5 (1.90)	12.5 (2.50)	3.5 (0.70)	5.0
	♀	41.5	6.1 (1.19)	10.0 (1.96)	14.0 (2.74)	3.6 (0.71)	5.1
Third leg	♂	47.7	6.5 (1.18)	11.5 (2.09)	19.0 (3.45)	4.9 (0.89)	5.5
	♀	54.5	7.0 (1.18)	13.0 (2.20)	21.0 (3.55)	5.1 (0.86)	5.9
Fourth leg	♂	40.0	6.0 (1.50)	11.0 (2.77)	9.0 (2.25)	6.5 (1.62)	4.0
	♀	42.2	6.5 (1.30)	12.0 (2.40)	9.8 (1.96)	7.0 (1.40)	5.0
Fifth leg	♂	—	—	—	—	—	—
	♀	47.0	6.5 (1.16)	13.2 (2.35)	11.5 (2.05)	8.0 (1.42)	5.6

Appendix masculina: distal piece pyriform in outline, 1.2 times as long as wide measured in the widest region, fringed with thickly set setae along inner edge and sparsely set ones along distal edge (Fig. 58, *I*).

Petasma: median lobe extends more or less beyond distal margin of lateral lobe, rounded at apex; lateral lobe serrated with many acute setae along distal border (Figs. 20, *E* and 25, *G–I*).

Thelycum: apical projection of anterior piece wider than long; seminal receptacle circular in outline, as long as wide (Fig. 49, *G*).

Cardiac plate furnished with about 17 equidistant spinules arranged in a longitudinal row. Zygocardiac ossicle has a longitudinal series composed of 9 conical teeth along about the same level of the spinules set on cardiac plate (Fig. 78, *A*). Prepyloric carries about 8 teeth on each postero-lateral edge (Fig. 73, *Q* and *W*).

The description given above is based on a male, 129 mm in body-length (33.2 mm in carapace-length), and a female, 135.5 mm long (35.0 mm in carapace-length).

Both specimens were obtained off South coast of Borneo.

Distribution: Off Australian coast from Port Jackson to Port Darwin (HASWELL and SCHMITT).

Note: The rostrum of male specimen bears 6 teeth above and 3 ones below, posterior three of the former are placed on carapace, but that of the female is armed with 6 teeth on upper rim as is the case with the male and 2 ones on inferior edge.

The third maxillipeds are sexually dimorphic as set forth already. All the pereiopods are, however, show no marked sexual modification in general aspect.

The writer can not gain access to HASWELL's original description. But the two specimens on hand well agree with the description and figures of SCHMITT (*op. cit*), and thus they are identified with the present species.

The present species is very similar to *Penaeus monodon* FABRICIUS; however, it is easily distinguished from the latter at least by possession of the following traits, viz., (1) the adrostral carina extends below the last postrostral spine instead of reaching considerably beyond the spine in question; (2) the cervical carina more steeply curves upwards; (3) the hepatic carina almost horizontal; (4) antennular flagella as long as the proximal two segments of the antennular peduncle; (5) the protuberance of the median lobe and the spines lying on distal margin of the lateral lobe of the petasma are more prominent; (6) the cardiac plate armed with about 17 spinules; and (7) the prepyloric ossicle has about 8 teeth on each of the postero-lateral margins.

Penaeus stylirostris STIMPSON

(Figs. 7, *H*; 20, *J*; 26, *A-C*; 47, *U*; 58, *N*; 73, *R* and *X*; 78, *B*; 117, *K*)

Penaeus stylirostris, BURKENROAD, 1934a, p. 87.

Rostrum styliform, reaches to or beyond tip of antennular peduncle, slightly bent downwards in proximal half and becomes horizontal in the rest; upper border armed with 8 teeth, posterior 4 of which are set on carapace, and the foremast one stands a little in front of half-way of the length; lower border bearing 2 teeth, first one of which is inserted just below the foremost one of upper series, and the other one at two-thirds. Postrostral carina gradully decreases in height posteriorly, reaches to about six-sevenths of carapace, provided with 2 or 3 ill-defined longitudinal pits on dorsal surface. Adrostral carina gets gradually weaker backward, extends a little in front of middle of carapace (somewhat posterior to epigastric tooth). Antennal carina well-developed. Gastro-orbital arcuate, much lowerer than the antennal, occupying about two-thirds of distance between post-orbital margin and hepatic spine. Cervical defined as well as gastro-orbital one, reaching to half-way toward center of carapace, but upper half very weak and bent toward dorsum. Hepatic carina a little more pronounced than gastro-orbital and cervical ones, slightly inclined antero-ventrally, extending from a point below epigastric spine to a point below the last post-rostral one. Supra-orbital and pterygostomian margins rounded. Atennal and hepatic spines small, subequal in size. Abdomen dorsally carinated backward to one-third of fourth somite, the carina of sixth somite ending in a minute point. Sixth pleonic somite about half the length of carapace, devoid of spinule at each postero-inferior angle. Telson tapering into an acute point, about thrice as long as wide measured in the widest region, subequal in length to sixth abdominal somite, provided with a deep dorso-median groove and no lateral armatures.

Prosartema more or less distally expanded with rounded apex, reaching middle of intermediate article of antennular peduncle. Stylocerite attains half-way of basal antennular segment. Antennular flagella asymmetrical; upper flagellum two-thirds the length of the other, somewhat longer than basal segment of the peduncle, lamellar in proximal half; inferior one longer than the peduncle, armed above in proximal one-third with well calcified acute setae directed obliquely backwards (Fig. 117, *K*). Antennal scale somewhat surpassing tip of antennular peduncle and much exceeded by distal margin of the lamella.

Mandible closely resembles that of *Penaeus japonicus*, palp extending to base of the last regment of antennal peduncle, distal segment twice as long as wide (Fig. 7, *H*). Maxillulary palp three-jointed. Maxilla belongs to Type-G_2. Palp of first maxilliped segmented into five. Second maxilliped normal in configuration. Third pediform, reaching far end of basal segment of antennular peduncle; ischium about two times the length of propodus which is about one and half times the length of propodus which is about one and half times the length of dactylus; merus subequal to carpus in length, 2.2–2.5 times as long as dactylus.

First, fourth and fifth pereiopods attain tip of stylocerite. Second stretching as far as third maxilliped. Third, the longest of all legs, reaches to apex of scaphocerite, proportions in length to dactylus: ischium 1.3–1.4, merus 2.5–2.8, carpus 4.3–4.9, and propodus ca. 1.

Fifth a little longer than fourth; merus and carpus subequal in length, ca. 2.6–2.8 times the length of dactylus; propodus more or less longer than ischium, 1.5–1.7 times as long as dactylus. Coxal plates of posterior three pairs of legs strikingly developed, those of third and fourth legs come into contact with each other (Fig. 47, *U*).

Appendix masculina: distal piece elongated with rounded apex, a little less than thrice as long as wide measured in the broadest region, fringed with setae in distal half of both lateral margins (Fig. 58, *N*).

Petasma is of Type–M_4; median lobe bluntly pointed at apex, extending slightly beyond apex of lateral lobe, posterior one-fifth of the lobe produced backward beyond basal edge of lateral lobe; lateral lobe covered with many short and stout setae on both inner and outer surfaces in subterminal portion, ventral margin curves dorsally in distal one-third and ends in a rather narrowly rounded apex (Figs. 20, *J* and 26, *A–C*). Thelycum belongs to Type–N_2, the last thoracic sternite has a conspicuous pyramidal prominence with a sharply defined posteromedian edge (Fig. 47, *U*).

Cardiac plate and zygocardiac ossicle closely related to those of *Penaeus brevirostris*, the former possesses about 29 spinules, and the latter 7–9 conical teeth of which the first one is much larger than others (Fig. 78, *B*). Prepyloric carries 5–7 pointed teeth on each posterolateral margin (Fig. 73, *R* and *X*).

The description given above is made from a male, 152.0 mm long (43.3 mm in carapace-length). Besides, two males and two females, 150–175 mm long (41–53 mm in carapace-length) were also examined.

Locality: Gulf of California (27° 06′ *N*; 110° 10′ *W*) (45 fathoms).

Distribution: Pacific coast of central America.

Note: The rostral spines are variable in number. The upper series consists of 7 or 8, posterior 4 of which are always situated on carapace. The lower ones range 2 to 4, anterior 1 or 2 of them are inserted before the foremost tooth of the dorsal border.

The inner antennular flagellum differs in feature with sex. As given above, that of male is provided with many short stout setae on upper border of proximal about one-third, whilst that of female is devoid of such setae whatever.

The third maxillipeds and all the pereiopods are not sexually dimorphic.

The outhor can not gain access to the original description of the present species. However, the five specimens examined herein agree well with the description given by BURKENROAD (*op. cit.*) with only exception that the inferior flagellum of the antennule is about one and half times as long as the upper one instead of being more than twice.

The present species exhibits a close resemblance to *Penaeus mono-*

don FABRICIUS. But there are many striking differences separating them from each other as given in the following table (Table 40).

Table 40.

Items	Present species	*Penaeus monodon*
1. Median groove of post-rostral carina	very shallow, discontinuous	considerably deep, continuous
2. Cervical carina	upper half hardly recognizable	well-defined in entire length
3. Hepatic carina	slightly (ca. 10°) inclined antero-ventrally	considerably (ca. 20°) tilted antero-inferiorly
4. Prosartema	about 0.26 as long as wide measured in the widest region.	about 0.14 times as long as wide measured in the widest region
5. Antennular flagella	upper flagellum shorter than the other which is a little longer than the peduncle, armed with many stout setae on upper rim of basal about one-third	upper flagellum longer than the other, much shorter than the peduncle, devoid of setae
6. Maxilla	belongs to Type-G_2.	belongs to Type-G_1.
7. Third maxilliped	belongs to Type-I_1.	belongs to Type-I_3.
8. Coxal plates of third to fifth legs of female	greatly developed.	somewhat developed in third leg only.
9. Distal piece of appendix masculina	about 2.7 times as long as wide.	about 1.3 times as long as wide.
10. Petasma	median lobe bluntly pointed at apex, slightly surpassing distal margin of lateral lobe; ventral margin curves dorsally in distal about one-third and ends in a narrowly rounded apex.	median lobe rounded at apex, which extends slightly beyond distal margin of lateral lobe, directed ventrally, ventral margin of lateral lobe well calcified, curves semicircularly upward in distal portion.
11. Thelycum	without seminal receptacle.	with seminal receptacle.

Genus ***Penaeopsis***, BATE (emend)

Penaeopsis, BATE, 1881, (A. MILNE-EDWARDS MS), p. 182; 1888, p. 273. BURKENROAD, 1934 b, (part), pp. 4–12.

Rostrum well-developed with teeth. Antennal and hepatic spines exist. Cervical and hepatic carina present. Both longitudinal and transverse sutures of carapace absent. Telson tapering into a point, armed with mobile and fixed dorso-lateral spines. Antennular peduncle has a spine on subterminal ventromedian border of first segment. Maxillulary palp unsegmented. All thoracic appendages with an exopodite. Appendix masculina is of Type–O_1. Petasma belongs to Type–M_2 (symmetrical, unjointed). Thelycum rather simple. Pterocardiac and zygocardiac ossicles are of Type–Q_3 and Type–R_2 respectively.

A pleurobranchia present on each thoracic somite from third to seventh; a rudimentary arthrobranchia on the first, a pair of arthrobranchiae on the somites from second to sixth, but one on the seventh; a podobranchia on the second only; and a mastigobranchia on the first, second, and fourth to sixth (Table 6, *F*).

The genus, *Penaeopsis*, was very imperfectly restricted by BATE (1881), with the result that greatly divergent groups of *Penaeids* with asymmetrical petasma and also of *Metapenaeus affinis* (H. MILNE-EDWARDS)–series, have been placed under the generic title by most of previous investigators. On the other hand, the species, *Penaeus rectactus* BATE, which has been regarded to be the nearest to, or identical with, the genotype of the present genus, *Penaeus serratus* BATE, has been variously identified by many prior authors: with *Penaeus* (*Parapenaeus*) by ALCOCK (1901), with *Parapenaeus* by ALCOCK (1906), DE MAN (1911), BALSS (1925), and YOKOYA (1933); with *Metapenaeus* by WOOD-MASON (1891), and ALCOCK and ANDERSON (1894); and with *Penaeopsis* (*Penaeopsis*) by BURKENROAD (1934). But reference to either *Parapenaeus* or *Metapenaeus* appears to the present writer unnatural. The present species greatly deviates from *Parapenaeus* in possession of the following important distinctions: carapace without sutures, telson with mobile dorso-lateral spines in addition to fixed ones, primitive appendix masculina (Type–O_1), and a mastigobranchia present on sixth thoracic somite. From the *Metapenaeus* it differs in having branchiostegal spine, telson furnished with fixed dorso-lateral spines, "Parapenaeid spine" on basal antennular segment, unsegmented maxillulary palp, second and third pereiopods without basial spines, primitive appendix masculina and petasma (Type–M_2), an exopodite present on the last pereiopod, and an anterior vestigial arthrobranchia lacking on seventh thoracic somite.

BURKENROAD (1934 *b*) has of late included the species in question within the genus *Penaeopsis* together with *Penaeus serratus* BATE and *Penaeopsis megalops* (SMITH). But his genus, *Penaeopsis*, has been dealt with in a broad sense involving the Penaeids of *Metapenaeus affinis*-series and those with asymmetrical petasma besides above mentioned species.

Such being the case, the writer redefined BATE's *Penaeopsis* as given above examining a considerable number of Japanese specimens referable to *Penaeopsis rectactus* (BATE). Consequently the *Penaeids* with asymmetrical petasma, and those of *M. affinis*-series are removed to *Metapenaeopsis* (BOUVIER) and *Metapenaeus* (WOOD-MASON and ALCOCK) respectively, each of which will be given later on.

The present genus under the present definition may embrace, at least *Penaeopsis rectactus* (BATE), *P. serratus* (BATE), and *P. megalops* (SMITH).

Penaeopsis rectactus (BATE)

(Figs. 1, *H*; 8, *J*; 19, *C*; 23, *A* and *B*; 36, *K* and *L*; 47, *J*; 58, *P*; 76, *A* and *F*; 78, *K*; 118, *A–G*; 119).

Penaeus rectactus, BATE, 1888, p. 266, pl. 36, fig. 2.

Peneus (Parapeneus) rectactus, ALCOCK, 1901, p. 17.

Parapeneus rectactus, ALCOCK, 1906, p. 33, pl. 6, fig. 19.

Parapenaeus rectactus, DE MAN, 1911, pp. 82-83; BALSS, 1925, p. 228; YOKOYA 1933, p. 9.

Metapenaeus rectactus, WOOD-MASON, 1891, p. 274; ALCOCK and ANDERSON, 1894, p. 145.

Penaeopsis (Penaeopsis) rectactus, BURKENROAD, 1934 b, pp. 5, 8 and 13.

Carapace a trile less than a quarter of body-length without rostrum. Post-rostral carina sharply defined, rather abruptly vanishing at middle of carapace, provided with a small epigastric tooth directed obliquely forward at about two-thirds. Cervical carina clearly cut, almost straight, reaches to mid-way to posterior end of post-rostral crest. Hepatic carina sharply defined forward to hepatic spine alone, parallel to cervical one, becomes horizontally in anterior one-third and continus to branchiostegal spine. Branchiocardiac ill-defined, hardly recognizable in larger specimens than 110 mm long. Antennal and hepatic spines present besides epigastric and branchiostegal ones, but the supra-orbital absent. Pterygostomian edge somewhat angulated. Abdomen dorsally rounded in anterior three somite, whilst the rest sharply carinated. Sixth pleonic somite with a small spine at extremity of dorsal carina, without cicatrices. Telson armed with two pair of minute movable spines at about two-fifths and midway respectively and a pair of prominent fixed ones at two-thirds, which are greatly exceeded by sharply pointed tip of telson.

Antennular peduncle 4, 1 and 1.5 in relative length of the segments from first to third respectively; basal segment has an acicular spine, nearly reaching to distal end of the segment, at three-fourths of inner ventral border. Prosartema lanceolate, hardly reaches to far end of first antennular segment. Antennular flagella asymmetrical; upper ramus a little shorter than carapace and considerably thickened in proximal half in male, simply tapering and about half as long as carapace in female; lower one considerably longer than carapace, ventrally curved forming a semicircular loop in proximal quarter, and gradually gets filamentous anterior to the loop in male, normal and a little more than half the length of carapace in female.

Mandible is characterized as follows: molar process with considerably indent triangular masticatory surface, sharply defined inner edge, and pointed both antero-median and posterior angles; incisor one rather thin, with a minute notch at about two-thirds of cutting edge; palp reaching base of the last joint of antennal peduncle, made up of two foliaceous segments, proximal one assuming the outline of an inverted triangle, and the other suboval, more or less narrowed anteriorly, about one and half times as long as wide measured at the broadest region, thrice as long as basal one (Fig. 8, *J*). Maxillulary palp lamella, truncate at end, carries a large expansion with rounded apex directed anterolaterally at middle of anterior margin and a prominent seta at antero-median angle (Fig. 118, *C*). Maxilla closely related to that of *Penaeus japonicus* (Fig. 118, *D*). First maxilliped is of Type-H_{2a}; endopodite five-segmented, proportions in length to the last segment: first 2, second 0.5, third 0.4, fourth 0.8; exopodite rather narrow, six times the width, distal quarter gently narrowed into a point. Second maxilliped inverted J-shaped, proportions in length to dactylus: merus 1.8, carpus 0.7, propodus 0.5; meropodite two-fifths as wide as long. Third maxilliped reaches to distal end of second antennular segment in male, but to tip of the peduncle in female, proportions in length to dactylus: ischium 1.95, merus (measured ventrally) 0.95, carpus and Propodus 1.5 in male, but 2.2, 1.0, 1.7, 1.44 in female respectively.

First cheliped extending to distal end of carpocerite, armed with both basial and ischial spines; palm about half the length of movable finger. Second extends beyond distal rim of carpocerite by finger which is one and half times as long as palm. Third reaches to, or beyond, mid-way of intermediate antennular segment in male, but always behind mid-way of the last segment of the peduncle in female, proportions in length to dactylus: ischium 1.6, merus 3.6, carpus 5, propodus 1 irrespective of sex. Fourth stretching as far as first cheliped, distal three segments markedly thinner than others, about half in size. Fifth hardly reaches to distal end of basal antennular segment in male, to far end of the second of the stalk in female, proportions in length to the last joint: ischium 1.6, merus and carpus 4.5, propodus 1.9 in both sexes; distal three joints thinner than proximal ones likewise in the fourth.

Exopodites of the pereiopods very minute.

Appendix masculine allied to that of Penaeids of *Penaeus* and *Miyadiella;* distal piece semicircular in outline, measures in length ca. 80% of the width (Fig. 58, *P*).

Petasma belongs to Type-M_2; dorsal lobule of lateral lobe forms a bluntly pointed horn directed postero-medially at proximal end; distal margin of ventral lobule of lateral lobe curves antero-medially and ends in a large well-calcified acute tip reaching to median line (Fig. 23, *A* and *B*).

Thelycum consists of an antero-median and a pair of posterior lobes, and a small fig-shaped median boss extending forwards from posterior edge of the last thoracic sternite; anterior lobe lying on sternite between penult pereiopods, inverted heart-shaped, a little shorter than wide, covering about 70% of distance between the pereiopods; posterior ones occupy most part of the last thoracic sternite, overlaps postero-lateral edges of anterior lobe, medially fused with each other and strongly depressed, with rounded outer margins (Fig. 47, *J*).

Cardiac plate possesses about 20 pointed spinules (Fig. 78, *K*). Cardiac ossicle well-calcifided, assuming the outline of an inverted bell, as long as wide measured at middle (Fig. 118, *G, a*). Pterocardiac is of Type–Q_3 (Fig. 118, *G, b*). Prezygocardiac pointed in both inner and outer ends, strongly curves postero-medially in inner subterminal portion, with anterior margin almost straight and the posterior considerably convex (Fig. 118, *G, c*). Urocardiac about five times as long as wide measured at middle, assumes the outline of an inverted anchor with truncate anterior rim and a pair of large pointed projections directed sidewise near anterior extremity (Fig. 76, *A*).

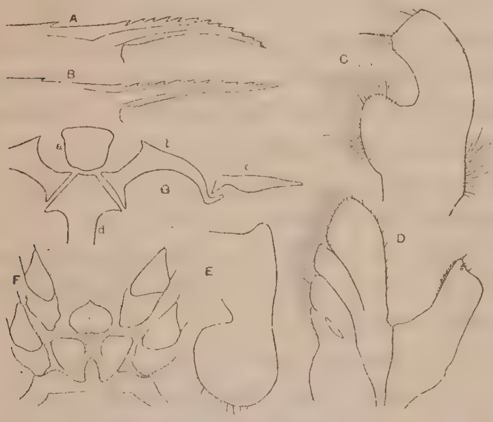

Fig. 118. *Penaeopsis rectactus*. *A*, rostrum of a male, 64 mm long (14.5 mm in carapace-length), ×2; *B*, rostrum of a male, 91.5 mm long (21.5 mm in carapace-length), ×1.4; *C*, endopodite of maxillula, ×16; *D*, maxilla without exopodite, ×8.4; *E*, appendix masculina of a male, 60 mm long (14 mm in carapace-length), ×8.8; *F*, thelycum of a female, 65 mm long (15 mm in carapace-length), ×4.8; *G*, cardiac (*a*), pterocardiac (*b*), prezygocardiac (*c*), and urocardiac (*d*), ossicles, ×8.4.

Zygocardiac is of Type–R_2 (Fig. 78, *K*). Prepyloric one comparatively short with about 8 conical teeth along each postero-lateral margin, proximal 3 or 4 of which are much smaller than others (Fig. 76, *A* and *F*).

The above mentioned description is based on a male, 104 mm long (24.2 mm in carapace-length), and a female, 118 mm long (31.8 mm in carapace-length). Other 35 males, 58.5–103.5 mm long (24.9–31.5 mm) and 20 females, 62.0–131.2 mm long (14.1–34.0 mm) were also examined.

Locality: Kumanonada (ca. 400 m), off Owase, Mie Pref.

Distribution: Fiji Islands, Philippines (BATE); Andamans (ALCOCK); Bali Sea, Paternoster Islands, Makassar Strait (DE MAN); Nicobar

Islands (BALSS); Off Owase and Tenryûgawa, Japan (YOKOYA).

Note: The rostrum exhibits some extents of variation in shape in accordance with growth. As given in Fig. 118, *A* and *B*, it appears considerably arcute in younger specimens, but it is almost straight and slightly tilted upward in larger specimens at least 90 mm long without rostrum.

The rostral teeth including epigastric one range in number from 8 to 13, and mostly 11 as given below.

Number of rostral spines	8	9	10	11	12	13
Frequency	1	0	11	25	8	2

The lengths of the third maxilliped, third cheliped and fifth limbs are found slightly different with sex as set forth above. But the relative growths of these appendages in relation to carapace-length are almost the same irrespective of sex (Fig. 119).

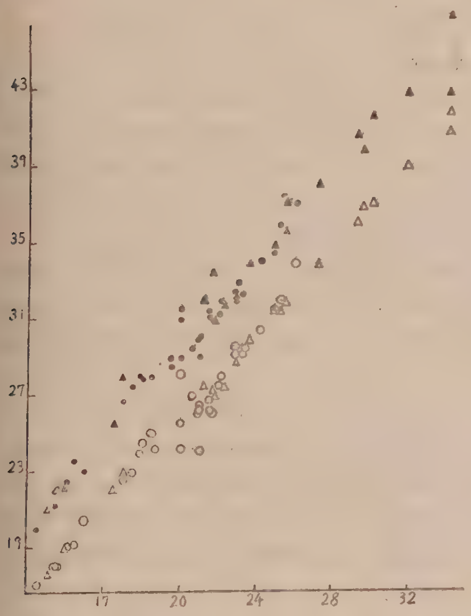

Fig. 119. Relative growths of third maxilliped (soft marks) and third cheliped (solid marks) of *Penaeopsis rectactus* in relation to carapacial-length (dimension in mm). Circles, male; triangles, female.

The basial spines of the second cheliped have been believed being present or absent. But no specimen with such armature has come under examination.

The appendix masculina of a rather young specimen, 60 mm long (14 mm in carapace-length) is simple, measuring 2.8 mm in total length, its distal half circular in outline. The articulation to occur between proximal and distal pieces has not yet defined (Fig. 118, *E*). It is very interesting from phyletic point of view that the general configuration is closely related to that of the animals belonging to the genera, *Penaeus* and *Miyadiella*.

The thelycum of young specimen, 65 mm long (15 mm in length of arapace) differs from that of the adult form in many respects as follows: he anterior lobe much wider than long; each of the posterior lobes arrowly rounded at apex which is directed antero-laterally, and the ntero-median edge does not yet reach the anterior lobe; and the median oss of the posterior ridge of the last thoracic sternite is still ogival in utline (Fig. 118, *F*).

The specimens dealt with well agree with descriptions and figures given by BATE (1888) and ALCOCK (1906) in all important characters, although differ from them in some minute points as given below. The rostrum straight, slightly directed upward as described by DE MAN (1911, p. 82), but horizontal in BATE's specimens. The cicatrices on the sixth pleonic somite are absent, although they are represented well-marked in BATE's Pl. 36, fig. 2. The lower antennular flagellum, which has a semicircular loop in male, much longer than the upper ramus, but it is delineated shorter in Pl. 6, fig. 19 given by ALCOCK (1906).

The present specimens are in accordance with the description given by DE MAN (1911, pp. 82 and 83), except the following two points:

Items	Present specimens	DE MAN's description
(1) Postrostral carina	present	absent
(2) Distolateral spines of petasma	directed anteromedially	directed forwards

The carina of our specimens is sharply defined without exception in anterior half of carapace as is the case with BATE's ones, and the distolateral spines of petasma are always found strongly curved inwards in even young specimens. Thus if DE MAN's description is true, his specimens should not be referred to the present species.

The young specimens dealt with strikingly tally with BATE's *Penaeus serratus* (1888, p. 268, Pl. 37, fig. 1) from Fiji. But the thelycum appears not conformable, thus the present author has not identified the present species with *P. serratus*.

The present species is very similar to *Penaeopsis megalops* (SMITH) (BURKENROAD, 1934 b, pp. 12–15), an Atlantic form, and it has been a question that these two species are identical or not. But the present species is probably different from *Penaeopsis megalops* as suggested by BURKENROAD (*loc. cit.*) at least in the respects given below according to his description.

Items	*P. rectactus*	*P. megalops*
(1) Rostrum	with 8-13 (mostly 11) teeth, non of which placed on carapace	with teeth more than 14 (mostly 18), one of which is always set on carapace
(2) Thelycum	Postero-lateral margins of median plate overlaped by anteromedian margins of lateral plates	postero-lateral margins of median plate overlap anteromedian margins of lateral plates

Besides these, the inclination of the hepatic carina of BURKENROAD's *P. megalops* is steeper than that represented in BATE's Pl. 37, Fig. 1 for *Penaeus serratus*. In material at the writer's disposal, it is very typical to that, although it is as a whole not so steep in larger specimens.

Genus *Metapenaeus*, WOOD-MASON and ALCOCK (emend)

Metapenaeus, WOOD-MASON and ALCOCK, 1891, p. 271; BURKENROAD, 1934 b, pp. 4 and 29.

Metapeneus, ALCOCK, 1906 (part), p. 16.

Penaeopsis, DE MAN, 1911 (part), pp. 53-55, and p. 61; BALSS, 1914 (part), pp. 6-7; 1925 (part), p. 228; KEMP, 1915 (part), p. 321; SCHMITT, 1926 (part), pp. 319-323.

Shell partly setose or glabrous. Carapace having neither longitudinal nor transverse sutures. Rostrum with teeth above alone. Cervical groove well-marked. Hepatic one well developed with sharply defined inferior (or posterior) edge forward to hepatic spine only. Antennal and hepatic spines present. Pterygostomian angle rounded. Abdomen entirely or partly carinated on dorsum. Telson tapering into an acute point, bearing a dorso-median groove, with or without movable lateral spines. First antennular segments lacking spines on ventral disto-median border. Antennular flagella shorter than carapace except rostrum. Maxillulary palp two-segmented, distal one of which is minute. Pereiopods from first to third with a basial spine, and that of the first with or without an ischial spine. Exopodite absent on fifth pereiopod. Appendix masculina is of Type–O_5. Petasma belongs to Type–M_9, thelycum Type–N_7. Branchiae: a pleurobranchia, an anterior filamentous and a posterior arthrobranchiae present on seventh thoracic segment, and a mastigobranchia on the sixth (Table 6, *G*). Pterocardiac ossicle is of Type–Q_1, and zygocardiac Type–R_6.

The present genus bears a close resemblance to the genus, *Parapenaeus*, however, it may be distinguished from the latter by the annexed features, viz., carapace without sutures, telson without fixed spines, maxillulary palp two-jointed, exopodite of all pereiopods not rudimentary, third maxilliped, second, third pereiopods with basial spine, petasma being of Type–M_9, appendix masulina Type–O_5, ptero-cardiac ossicle Type–Q_1, and zygocardiac Type–R_6.

Further, the present genus and *Trachypenaeopsis* show close affinity in the features of such characters, as follows:—maxillulary palp, petasma, thelycum, and zygocardiac ossicle. But the former is easily separable from the latter in having telson without fixed spine, third maxilliped unarmed, without basial spine, second and third pereiopods with basial spine, seventh thoracic somite with a pleurobranchia, and fifth pereiopod furnished with no exopodite.

The branchial arrangements suggest, to some extent, inter relationship of the genera. Thus *Metapenaeus* may be said to be related to *Metapenaeopsis*, *Penaeopsis*, and *Parapenaeus* in possession of pleurobranchia on each thoracic somite from third to seventh, to *Metapenaeopsis* (except *M. lamellutus*), *Trachypenaeopsis*, *Eusicyonia*, *Hymenopenaeus*, and *Parahaliporus* in having 13 arthrobranchiae, to *Metapenaeopsis*, *Trachypenaeopsis* and *Eusicyonia* in having even likewise very rudimentary anterior arthrobranchia on seventh thoracic somite, and to *Atypopenaeus*, *Metapenaeopsis*, *Penaeopsis*, *Trachypenaeopsis*, *Trachypenaeus*, *Miyadiella*, and *Eusicyonia* in having mastigobranchia on sixth thoracic somite but no mastigobranchia on the third.

Key to the species of *Metapenaeus*

- A_1 Body with many setose depressed areas; ischial spine of first pereiopod present or absent
  - B_1 First pereiopod provided with an ischial spine
    - C_1 Rostrum with 6–9 (mostly 8) teeth on upper border; abdomen dorsally carinated from first to sixth somites; telson unarmed; second segment of antennular peduncle thrice as long as third one; upper antennular flagellum about half the length of carapace; merus of second maxilliped 3 times as long as wide; ischial spine of first leg much smaller than basial one; fourth leg of female without coxal projection; disto-median projection of petasma greatly surpassing tip of disto-lateral one; thelycum with an antero-median plate, without a median boss close to posterior edge of the last thoracic sternite; cardiac plate with 25–27 spinules arranged in a longitudinal row ....*M. monoceros* (FABRICIUS).
    - C_2 Rostrum with 9–11 teeth above; abdomen dorsally carinated posterior to middle of fourth somite; telson armed with 3 pairs of movable spines; second segment of antennular peduncle twice the length of third one; upper antennular ramus about a quarter as long as carapace; merus of second maxilliped 2 times as long as wide; ischial spine of first leg subequal to basial one in size; fourth leg of female with a well-developed coxal projection; disto-median projection of petasma extends as far as disto-lateral one; thelycum without antero-median plate, has a conical median boss close to posterior rim of the last thoracic sternite; cardiac plate with 41–43 spinules alined longitudinally ....*M. intermedius* (KISHINOUYE).
  - B_2 First pereiopod without an ischial spine
    - D_1 Rostrum long, reaching beyond distal end of basal segment of antennular peduncle, not triangularly lifted at base
      - E_1 Upper antennular flagellum somewhat less than half the length of carapace; carpocerite reaches below middle of cornea, twice as long as wide; petasma 2.5 times as long as wide, disto-median projection hood-like, disto-lateral one directed sidewise; lateral plate of thelycum C-shaped with sharply pointed anterior end; cardiac plate has 32–35 spinules alined longitudinally ....*M. affinis* (H. MILNE-EDWARDS).
      - E_2 Upper antennular flagellum ca. 0.8 times as long as carapace; carpocerite extends as far as eye, thrice as long as wide; petasma about thrice as long as wide, disto-median projection slender, with pointed apex, recurved dorsally and backward, disto-lateral one directed antero-laterally; cardiac plate with 23–25 spinules
        - F_1 Postrostral carina reaches eight-ninths of carapace; pleon dorsally carinated from first to sixth somites; fifth pereiopod reaches to or beyond far end of carpocerite ....*M. joyneri* (MIERS).
        - F_2 Postrostral carina extends about middle of carapace; second and

third pleonic segments without mid-dorsal carina; fifth pereiopod surmounts tip of scaphocerite by dactylus

.........*M. gracilipes* sp. nov.

D₂ Rostrum short, not reaching distal end of first segment of antennular peduncle, triangularly elevated at base, with 6 teeth above; thelycum with a median and a pair of lateral plates which are broad and suboval in outline, subequal in size; cardiac plate with 10-12 spinules

.........*M. lysianassa* (DE MAN).

A₂ Body uniformly glabrous; ischial spine of first pereiopod present

G₁ Telson unarmed; upper antennular flagellum half the length of carapace; fifth leg surmounts tip of scaphocerite by dactylus; median plate of thelycum larger than lateral ones ....*M. brevicornis* (H. MILNE-EDWARDS).

G₂ Telson armed with two pairs of lateral spinules; upper antennular flagellum two-thirds the length of carapace; fifth pereiopod surpassing scaphocerite by major part of propodus and dactylus; median plate of thelycum smaller than lateral ones ....*M. spinulatus* sp. nov.

Metapenaeus monoceros (FABRICIUS)

(Figs. 1, *I*; 7, *Q*; 22, *A*; 31, *E* and *F*; 40, *L-O*; 47, *B*; 52, *H* and *I*; 62, *D* and *D'*; 68, *G*; 74, *D* and *J*; 81, *E*; 120; 121)

Metapenaeus monoceros, BURKENROAD, 1934 b, pp. 32-33.

Metapeneus monoceros, ALCOCK, 1906, p. 18, pl. 3, figs. 7, 7a-c; MAKI and TSUCHIYA, 1923, pp. 39-41, pl. 3, fig. 4.

Penaeopsis monoceros, DE MAN, 1911, pp. 55-57, pl. 6, fig. 14, BALSS, 1914, p. 7; KEMP, 1915, 321; 1918, p. 294; PARISI, 1919, p. 61; SCHMITT, 1926, pp. 325-326; OSADA, TANIZAKI and NAKAZAWA, 1931, p. 5, pl. 2, upper (right); BOONE, 1935, pp. 71-75, pl. 18; YU, 1935, pp. 164-165; YOSHIDA, 1941, p. 13, pl. 11, fig. 3.

Penaeus monoceros, LATREILLE, 1808, p. 250; H. MILNE-EDWARDS, 1837, p. 415; DANA, 1852, p. 605, pl. 40, fig. 5; MIERS, 1878, p. 301; DE MAN, 1892, pp. 513-515, pl. 29, fig. 54; ORTMANN, 1890, pp. 450-451, pl. 36, fig. 3a, b; DOFLINE, 1902, p. 631.

Penaeus incisipes, BATE (part), 1888, p. 257 258, pl. 34, fig. 2; KISHINOUYE, 1900, pp. 18-19, pl. 4, fig. 2 and pl. 7, fig. 6; RATHBUN, 1902, p. 38.

Carapace pilose except glabrous carinae and marginal regions. Postrostral carina well-marked, extending to posterior margin of carapace. Antennal and branchio-cardiac carinae rather pronounced, but hepatic one sharp. Adrostral grooves narrow, reaching one-third of carapace (a little behind epigastric spine). Post-ocular grooves clearly cut, laid down postero-laterally at an angle of ca. 40° against dorso-median line of carapace. Orbito-antennal, cervical and hepatic groove well-defined, meet in front of hepatic spine. Cervical ones straight, runs postero-medially, reaching mid-way toward center of carapace. Hepatic one C-shaped, extending slightly behind anterior margin of carapace. Pterygostomian margin rounded. Supra-orbital, epigastric, antennal and hepatic spines only present, first of which is minute, but the rest rather large, subequal in size, and epigastric inserted slightly forward to a third of carapace. Abdomen also setose, furnished with glabrous low irregular ridges on each lateral surface of anterior 5 somites and 3 longitudinal wavy ones on the surface of sixth somite, dorsally carinated through first 6 somites, but the carina gets gradually sharper backward. Sixth pleonic somite armed with 3 spinules, one of which is located at far end of mid-dorsal carina and other 2 at each postero-inferior angle. Telson clad with fine setae likewise carapace and abdomen, 1.3 times the length of sixth pleonic somite, and two-thirds the length of carapace (Fig. 120).

Prosartema narrow, hardly reaching to far end of first antennular joint, stylocerite attains about middle of the segment. First segment of antennular stalk armed with a large, short spine on upper antero-median edge, besides a minute one lying at antero-lateral angle. Antennular flagella cylindrical, simply tapering; upper one somewhat longer than the other, a little less than half as long as carapace. Basicerite without or with a vestigal tooth on antero-lateral edge. Scaphocerite somewhat surpassing tip of antennular peduncle.

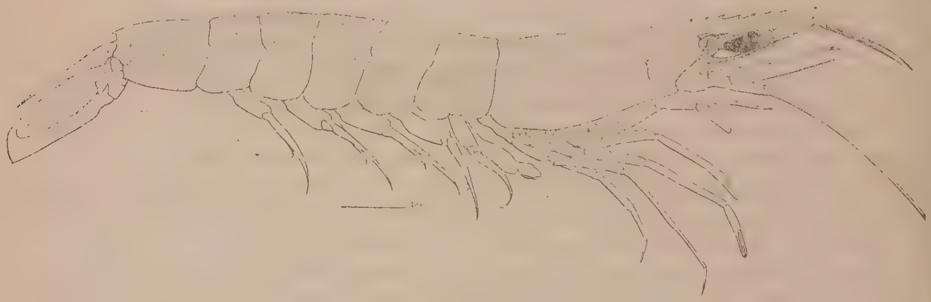

Fig. 120. *Metapenaeus monoceros* (FABRICIUS), male, 110 mm long, secured from Sashiki, Kumamoto Pref.

Mandibular palp reaches middle of third segment of antennular peduncle; basal segment invertedly subtriangular in outline, a little longer than wide measured in the widest region; distal one narrowly rounded at apex, markedly convex in two-thirds of outer edge, about twice or five times as long as wide measured at the widest and subterminal regions respectively (Fig. 7, *Q*). Maxillularly palp composed of two segments, first segment foliaceous, with wavy anterior border which has a spinous seta at three-fourths, and somewhat convex posterior one bearing a protuberance with rounded apex near base; the second very minute with rounded apex, one-ninth the length of basal joint. Maxilla is of Type–G_1. First maxilliped belongs to Type–H_{2a}; endopodite consisting of five joints, ratios in length to fifth joint: first 1.1, second 0.3, third 0.7, fourth 1. Second maxilliped inverted J-shaped, proportions in length to dactylus: ischium 0.5, merus 1.4, carpus 0.6, propodus 0.7; meropodite thrice the width.

Third maxilliped hardly reaching far end of carpocerite; ischium and merus subequal in length, about 1.2 times as long as carpus or propodus which are ca. 1.6 times the length of dactylus.

Third cheliped reaching middle of carpocerite, has both basial and ischial spines, of which the latter is very minute, proportions in length to movable finger: ischium 1.2, merus 1.5, carpus 1.4, propodus 0.65; fingers slender, with straight cutting edges and pointed tips. Second one extending beyond distal rim of carpocerite by fingers, armed with only a basial spine which is as large as that of first cheliped. Third one hardly reaches to tip of antennular peduncle, has a basial spine a little smaller than that of second leg, ratios in length to movable finger: ischium 1.1, merus 2.3, carpus 3.2, propodus 0.9; merus about 5 times as long as wide, twice as wide as distal portion of carpus. Fourth pereiopod attains distal edge of basicerite, proportions in length to dactylus: ischium 1.3, merus 2.3, carpus 2, propodus 1.3; coxa provided on postero-median surface with a well-calcified protuberance which comes into contact with anterior plate of thelycum. Fifth one somewhat surmounts distal end of first segment of antennular peduncle, slenderer than any preceding pereiopods, specialized in male as described and illustrated by KISHINOUYE (1900) and ALCOCK (1906), proportions in length to dactylus: ischium 1.1 merus 2.7, carpus 2.5, propodus 1.6.

Appendix masculina well-calcified; distal piece ca. 1.4 times the length of proximal one, with a deep pit on apical surface (Fig. 62, *D* and *D'*).

Petasma (Figs. 31, *E* and *F* and 40, *L–O*) and thelycum (Figs. 47, *B* and 52, *H* and *I*) belong to Type–M_9 and Type–N_7 respectively. Descriptions and illustrations of their adult form and metamorphoces are given already in the general part of this paper.

Cardiac plate armed with 25–27 spinules (Fig. 81, *E*). Zygocardiac ossicle has two longitudinal rows on inner surface, each of which consists of about 10 well-calcified, large, thickly set conical teeth which gradually increase in size towards middle; the teeth of upper row directed dorsomedially and those of the other ventromedially (Fig. 81, *E*). Urocardiac subrectangular in outline, but bluntly pointed at anterior end and produced sidewise with rather buntly pointed apex on each anterior subterminal lateral edge (Fig. 74, *D*). Prepyloric subpentagonal in dorsal view, tapers into a large bluntly pointed median tooth in posterior half, furnished on each posterolateral margin with 6–9 acuminate teeth which get gradually larger in size backward, but much smaller than the median tooth (Fig. 74, *D* and *J*).

The description given above is mostly based on a male, 132.0 mm long (35.1 mm in carapace-length) and a female, 145.4 mm long (41.5 mm in carapace-length), obtained from Sashiki, Kumamoto Pref. Besides these, 65 specimens (37♂, 28♀), 50.6–142.0 mm long (13.7–41.2 mm) in carapace-length) were also examined.

Locality: Tokyo (Fish market); Miya, Aichi Pref.; Tomo, Hiroshima Pref.; Sashiki, Kumamoto Pref.; Macassar and Singapore collected by Mr. I. MATSUI; South coast of Borneo by Mr. S. SAITÔ.

Distribution: Okinawa (PARISI); off Southern Queensland (SCHMITT); Tale Sap, and Chilka Lake (KEMP); Penang Malay Straits, and Singapore (BOONE); Sagami, Kôchi, Maizuru (ORTMANN); Yokohama and Sagami Bay (DOFLEIN); Singapore, penang, Salangor, Port Said (Egypt), Hong Kong, Amoy (BURKENROAD); Amoy (YU); Wakanoura, Hiroshima and Nagasaki (RATHBUN); Sashiki (OSADA, TANIZAKI and NAKAZAWA); Tainan (MAKI and TSUCHIYA); Nippon (KISHINOUYE); Takao (BALSS). India (ALCOCK); Madura-strait, Bay of Bima, Macassar, Sumbawa, Java Sea (DE MAN).

Note: The rostrum reaches to or beyond the tip of the antennular peduncle in all our specimens, although BOONE (1935, p. 72) says "the rostrum is short, not quite extending to the distal margin of the antennular peduncle,......". The spines set on the upper edge of rostrum range 6 to 9 in number, and the modal number is 8 in both sexes (see below).

Number of rostral spines	6	7	8	9
Frequency	1	11	35	5

Among those spines, posterior 2 are always found on the carapace.

The longer (outer) antennular flagallum appears to be different with sex. As given in Fig. 121, *C*, the ramus of male is somewhat longer than that of the other sex.

The relative growths, as referred to the carapacial length, of the third maxilliped and all the pereiopods are linear in trend irrespective of sex. Remarkably enough, the relative growths of all the thoracic limbs of the specimens obtained from Singapore, Macassar and South coast of Borneo are somewhat larger than these of the Japanese specimens (Fig. 121, *A*, *B* and *D*). However, it will be settled in future, after a biometric examination dealing with a large number of specimens secured from the intermediate localities between Japan and such southern localities given above, whether the difference is geographical or specific.

The specimens dealt with agree well with the descriptions and illustrations given by KISHINOUYE, ALCOCK, DE MAN and BOONE. But these specimens stand at variance from BATE's *Penaeus incisipes* in the petasma and thelycum, especially in the latter. The petasma is represented as having a pair of antero-median hoodlike processes directed obliquely sidwise, and the thelycum bearing broad inverted heart-shaped anterior plate and no auriculate appendages on the last thoracic sternite, according to his illustrations (pl. 34, 2″ and 2‴).

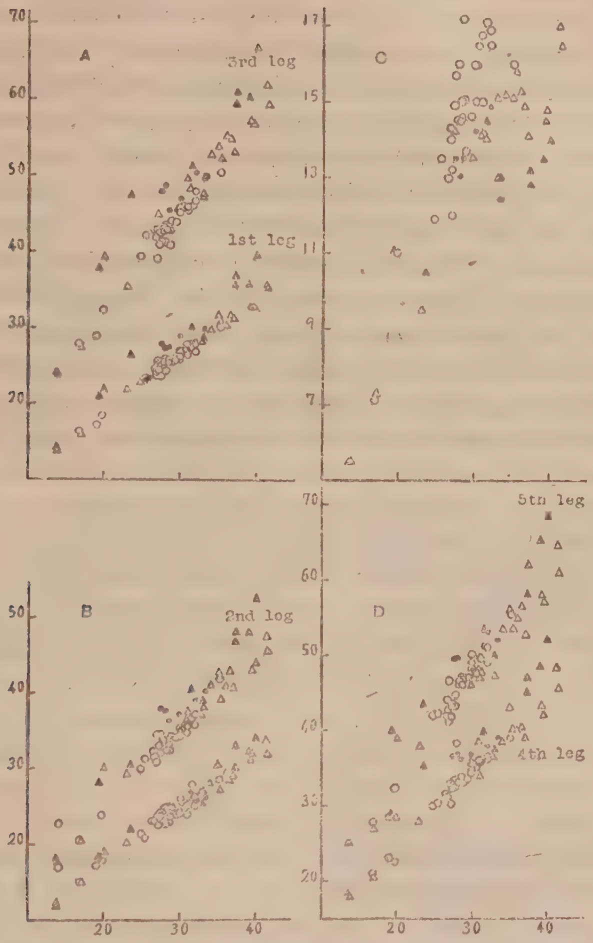

Fig. 121. Relative growths of *Metapenaeus monoceros* in relation to carapace-length (in mm). *A*, first and third pereiopods; *B*, third maxilliped and second limb; *C*, outer antennular flagellum; *D*, fourth and fifth pereiopods. Solid marks, specimens obtained from Macassar, Singapore, and South coast of Borneo. Soft ones, Japanese specimens. Circles, male; triangles, female.

Metapenaeus intermedius (KISHINOUYE)

(Figs. 7, *O*; 31, *I–L*; 47, *D*; 62, *E* and *E′*; 74, *Q* and *W*; 81, *L*; 122; 123).

Penaeus intermedius, KISHINOUYE, 1900, pp. 21–22, with a textfig.; KINOSHITA, 1930, pp. 269–270, with figs.

Penaeopsis ensis, YOKOYA, 1933, p. 9.

Shell furnished with irregular pubescent areas as shown in Fig. 122. Rostrum acute, styliform, slightly ascending, with straight upper and lower borders, bearing a well defined lateral ridge, extends as far as tip of antennular peduncle, five times as long as wide (without spine) when measured at base, armed above with 8–10 teeth (except epigastric one), posterior 2 of which are inserted on carapace, but toothless below. Postrostral carina abruptly ends at eight-ninths of carapace. Adrostral groove narrow, extending to a third of carapace. Post-ocular also narrow, deeply cut. Orbito-antennal broad and deep, meets with cervical groove in front of hepatic spine. Cervical one as deep as the orbito-antennal, straight, and attains about half-way toward the two-thirds of dorsum of carapace. Hepatic *C*-shaped, continuos to the cervical in front of hepatic spine, runs antero-inferiorly, extending a little behind frontal margin of carapace, subequal to cervical and orbito-antennal ones in depth. Supra-orbital angle defined, but not spiniform. Pterygostomian anglerounded. Epigastric, antennal and hepatic spines present, first of which stands at about a third of carapace, the last inserted below epigastric spine, smaller than the antennal. Abdomen dorsally carinated backward to middle of fourth somite, but the carina of fourth somite ill-defined, and that of the sixth ends in an acute spinule which is directed posteroventrally. Sixth pleonic somite about 1.1 times as long as wide, two-fifths the length of carapace. Telson sharply pointed at apex, a little less than thrice the width measured at the widest region, armed with 3 pairs of movable spines, first pair of which lie at three-fifths and the last at ca. seven-ninths, greatly exceeded by tip of inner uropods, about half as long as carapace.

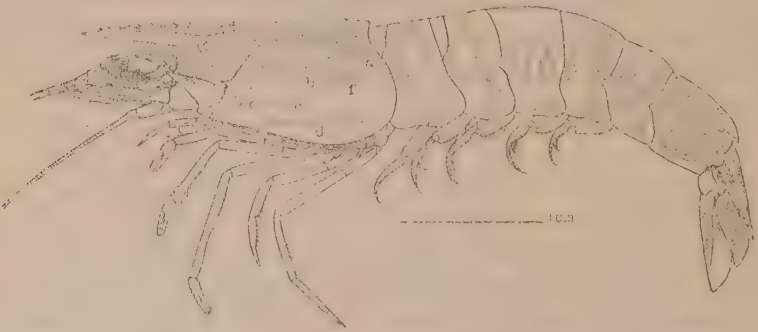

Fig. 122. *Metapenaeus intermedius* (KISHINOUYE) female, 142 mm long, obtained from Sashiki, Kumamoto Pref.

Antennular peduncle pilose, upper distal margin raised as a flattish projection. Prosartema narrow, stretching to far end of basal segment of antennular peduncle. Stylocerite attains middle of first article of the peduncle. Antennular flagella subequal in length, about a quarter the length of carapace. Basicerite without spine on distal outer edge.

Scaphocerite narrowed anteriorly by half, about 2.2 times as long as broad, furnished with a disto-lateral spine which is slightly exceeded by apex of lamella. Carpocerite stretching as far as stylocerite.

Mandible: molar process considerably concave on mastcatry surface; incisor one sharp on cutting edge which has two pointed teeth; palp attains third segment of antennal peduncle; basal joint invertedly triangular; distal one deeply excavated on disto-lateral edge, narrowly rounded at apex, 2.3 times as long as wide when measured at the broadest region, about 3.5 times the length of basal joint (Fig. 7, *O*). Maxillula, maxilla and first maxilliped closely resemble those of *Metapenaeus monoceros;* endopodite of maxillula has a spinous setae at three-fourths of anterior margin, distal árticle minute, a sixth the length of basal one. Second maxilliped 7-jointed, ratios in length to dactylus: coxa and propodus 0.9, basis 0.8, ischium and carpus 0.6, merus 1.4; meropodite twice the breadth. Third maxilliped reaching to far end of carpocerite, proportions in length to the last joint: merus and carpus 1.9, propodus 1.6.

First cheliped hardly reaching anterior margin of carpocerite, provided with a basial and an ischial spines; propodus equal to merus in length, more or less longer than chela. Second one attains far end of first segment of antennular peduncle, carrying a basial spine, proportions in length to movable finger: merus 2.5, carpus 3, palm 0.6. Third extending as far as tip of antennular peduncle, and has a basial spine, proportions against movable finger (5 mm): ischium 1.5, merus 3.1, carpus 4.7, propodus 0.8; merus about 5 times as long as wide. Fourth pereiopod reaches far end of basicerite, provided on postero-median surface of coxopodite with a well-calcified conspicuous projection directed backward reaching to middle of the last thoracic sternite (Fig. 47, *D*), relative lengths to dactylus: ischium and propodus 1.8, merus 3.0, carpus 2.5. The last leg extending as far as second cheliped, relative lengths to dactylus: ischium 1.5, merus 3.2, carpus 2.9, propodus 2.

Appendix masculina intimately related to that of *M. monoceros* (Fig. 62, *E* and *E'*).

Petasma is of Type-M_9, very closely resembles that of *M. monoceros;* disto-median processes extend as far forward as distolateral horns in rather young specimen, 80 mm long (Fig. 31, *I–L*).

Thelycum consists of a pair of ear-shaped lateral elevations lying antero-laterally at about middle of the last-thoracic sternite and a median bose ogival in shape, placed close to posterior ridge of the sternite (Fig. 47, *D*).

Cardiac plate provided with 40–43 spinules on inner surface (Fig. 81, *L*). Pterocardiac, prezygocardiac, zygocardiac, urocardiac and prepyloric ossicles (Fig. 74, *Q* and *W*) very similar to those of *M. monoceros* in general configuration; zygocardiac carries about 10 pairs of conical teeth (Fig. 81, *L*), and prepyloric about 8 ones on each postero-lateral margin.

The description given above is mostly based on a female, 142 mm long (40 mm in carapace-length) secured from Sashiki, Kumamoto Pref. Additional specimens including 3 males, 66.5–80 mm long (16.5–20 mm in carapace-length) obtained from Tanabewan, Wakayama Pref. and 2 females, measuring 27.5–36.1 mm in carapace-length, collected from Gokasyo-wan, Mie Pref., were also examined.

Distribution: Tosa (KISHINOUYE); Tanabe-wan (KINOSHITA).

Note: The antennular flagella are found about one-third the length of carapace in rather young males, whilst about a quarter in adult females. Such discrepancy may be, however, due to difference of size of specimens, since each of the measurments is included in the same category of the relative growth in relation to carapace-length.

The setose patches furnishing body-walls are subject to considerable age-variation, increasing in extent and number with advance of growth of the prawn. Remarkable changes occur in those to be found on the branchial region of the carapace and the abdominal segments from the second to the fourth as given in the following lines, so far as the present material is concerned. In the smallest specimen (male, 66.5 mm long without rostrum, and 16.5 mm in carapace-length), no patches are present on the branchial region. Three transverse ones lie much nearer to posterior margin than to the anterior on each side of the second pleonic somite, the lowest one is placed on the pleuron and greatly larger than other two which are still minute and subequal in size. Also three ones set on the third. Those of the fourth are five in number (Fig. 123, *A*). In a somewhat larger male, 80 mm long (20 mm in carapace-length), four ones (patches-*b*–*e*) make their appearance on the branchial region; the *b* and *d* are slender, running longitudinally and almost parallel with each other; the *c* and *e* are minute, and the *e* much smaller than the *d*. Those of the second amount to four in number adding another transverse one at about middle close to anterior margin. Six patches laid down on the third, three of which are still much smaller than the rest. An anterior and five posterior ones present on the fourth the anterior is slender, arising transversely from middle of the anterior border, the posterior five grow larger in size and more modified in shape than those of the specimen, 66.5 mm long, especially the uppermost one undergoes a remarkable modification and finally assumes L-shaped form by giving off posteriorly a transverse branch which runs nearly parallel to the posterior edge of the segment (Fig. 123, *B*). In the largest specimen, female, 142 mm long (40 mm in carapace-length), those of the branchial region amount to five in number by addition of another one (*f*) which is located between the *c* and *e*; and the *a* grows sidewise to be united with the posterior end of the *b*. In the second somite, a small patch newly occurs between the anterior and the intermediate one of the posterior series; and the postero-dorsal two are united with each other. Those of the third make no increase in number, but the uppermost takes a marked change in feature by putting forth a lobe anteriorly. Those of the fourth except the anterior and the pleural ones are conjoined with one another (Fig. 122).

The type specimen of *Penaeus intermedius* KISHINOUYE was deposited in the museum attached to the Fishery Institute, Faculty of Agriculture, Tokyo Imperial University, but unfortunately it was somehow lost. The writer, however, has of late had an opportunity to compare the specimens on hand with a photograph based on a specimen which is identified with *Penaeus intermedius* by the late Dr. K. KISHINOUYE himself through the courtesies of Dr. Y. YOKOYA of the above-mentioned Institute. Since all our specimens quite agree with the photograph, they are referred to KISHINOUYE's *Penaeus intermedius*, although they differ from the KISHINOUYE's illustration of this species as given in the following table 41.

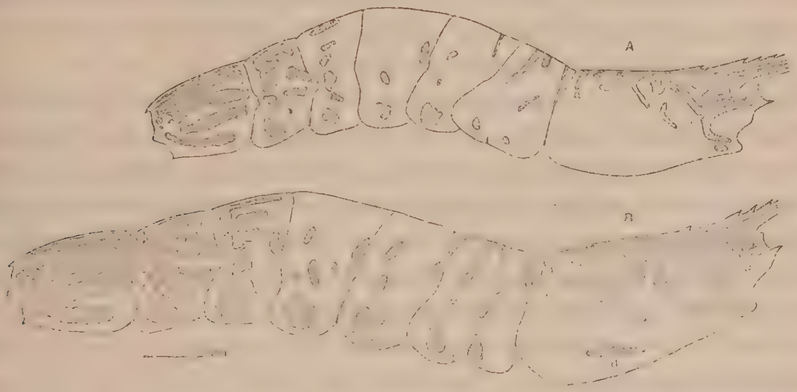

Fig. 123. *Metapenaeus intermedius* (KISHINOUYE), showing age-variation of setose depressed patches set on carapace and abdomen without telson. *A*, male, 66.5 mm long (16.5 mm in carapacial length); *B*, 80 mm long (20 mm in carapace-length).

Table 41.

Items	Present specimens	KISHINOUYE's illustration
1. Rostrum	straight, more or less inclined dorsally	horizontally straight with slightly upcurved tip
2. Branchial region of carapace	with three setose patches	naked

3. Terga of fourth and fifth pleonic somites	a little produced posteriorly on both sides of median incision	rather strongly produce backward
4. Lateral spines of telson	spines of first pair stand at three-fifths; those of third pair reaching to about middle of apical portion of telson	spines of first pair stand little anteriorly to middl those of third pair almos reaching to tip of telson

The present species is much allied to, sometimes confounded with *Penaeus ensis* De Haan (1850, p. 192, pl. 46, fig. 2), but it is, according to De Man (1922, p. 8), easily recognizable from *P. ensis* in havin rostrum straight and somewhat tilted upward, carapace without longitudinal carina backwards from hepatic spine to posterior edge of carapace and not having "a quite distinct flattened keel" on terga of posterio half of second and third pleonic somites. Besides these, the sixth pleoni somite is found without three cicatorices on lateral surfaces, and th antennular flagella are relatively shorter in the present material compared with the illustration given by De Haan.

The thelycum of a specimen from Singapore, which was referred t *Penaeopsis ensis* (De Haan) by Balss (1914, p. 8, fig. 2), strikingl resembles that of the present specimens, but slightly differs from it i the point that the median plate of the present specimens is so much pr duced anteriorly as to extend to about middle of the penult thorac sternite in the form of a sharply defined rather narrow ridge, althoug it gradually decreases in height anteriorlly.

Moreover, the specimens lying before the writer are closely relate to *Penaeopsis intermedia* var. *anchista* De Man (1922, pp. 5–8, pl. figs. 3 *a–d*), but differ from the latter in many respects as given belo (Table 42), on the basis of similar sized males (present specimen 80 m long, De Man's one, 77 mm long), and somewhat different sized female (present specimens 127 mm and 142 mm long, De Man's one, 80 m long).

Table 42.

Items	Present specimens	*P. anchista*
1. Cervical groove	reaching to about half-way toward two-thirds of postrostral ridge	reaching near post-rost ridge
2. Setose patch-*a* of carapace	present	absent
3. Tergum of first pleonic segment	with a K-shaped patch (dorsal view)	with a simply transver patch
4. Sixth pleonic segment	two-ninths longer than the greatest width	one-third longer than t greatest width

5. Petasma	disto-median appendages relatively larger, extending as far foward as disto-lateral projections, overlap distomedian margins of ventral lobules of lateral lobes by its postero-lateral angles; disto-lateral projections directed a little antero-laterally	disto-median appendages relatively smaller, much exceeded by tip of disto-lateral projections, not overlapping disto-median margins of ventral lobules of lateral lobes; disto-lateral projections directed almost anteriorlly.
6. Thelycum	with lateral plates directed antero-laterally; has a minute but well defined median boss in front of posterior ridge of the last thoracic sternite	possessing lateral plates directed sidewise; without a minute median boss in front of posterior ridge of the last thoracic sternite

Thus the present species and *Penaeopsis intermedia* var. *anchista* De Man may be not conspecific.

Burkenroad's (1934 b, pp. 36–40) specimens (two males, from Selangor, 104 mm, and from Singapore, 80 mm in total length; and a female from Hong Kong, 145 mm in total length), well agree with the present specimens in number of rostral spines, condition of setose patches lying on branchial region of carapace and presence of a minute median tubercle in front of posterior edge of the last thoracic sternite (in Chinese specimen). But the writer hesitate to believe that they are referable to the present species, inasmuch as they stand at variance with the present specimens at least in the following items.

Items	Present specimens	Burkenroad's specimens
1. Rostrum	straight	straight or a little upturned at tip
2. Rostral teeth	posterior 2 lying on carapace, the penult above post-orbital edge	posterior one only present on carapace
3. Petasma	disto-lateral projections extending as far forward as apexes of disto-median projections (in specimens, ca. 150 mm long according to Kinoshita)	disto-lateral projections overlap on disto-median projections (in specimen, 104 mm in total length)
4. Median plate of thelycum	extends as a high ridge to ca. middle of penult thoracic sternite	emarginate on anterior border

Finally the present species is very similar to *Penaeopsis endeavouri* Schmitt (1926, pp, 329–333, pl. 59, figs. 1–3 and pl. 68, fig. 4). However, it may be easily differentiated from the latter as given below.

Items	Present species	*P. endeavouri*
1. Rostrum	reaching tip of antennular peduncle, five times as long as deep	not reaching far end of second segment of antennular peduncle, about four times as long as deep
2. Antegastric groove	present	absent(1)
3. Coxal projection of fourth leg	extending to middle of the last thoracic sternite	not extending to middle of the last thoracic sternite
4. Petasma	disto-lateral horns much smaller than disto-median ones (2)	disto-lateral horns as large as distomedian ones
5. Thelycum	lateral elevations small, narrow; a median boss present close to posterior edge of the last thoracic sternite	lateral elevations large, broad; median boss absent

Metapenaeus affinis (H. MILNE-EDWARDS)

(Figs. 1, *E*; 4, *D*; 7, *P*; 22, *C*; 31, *A* and *B*; 40, *A*–*E*; 47, *C*; 52, *A*–*C*; 62, *C* and *C′*; 68, *H*; 74, *F* and *L*; 81, *F*; 124; 125, *A*–*D*).

Metapenaeus affinis, BURKENROAD, 1934 b, pp. 29-32; RATHBUN, 1906, p. 903.

Metapeneus affinis, ALCOCK, 1906, p. 20, pl. 3, fig. 8, 8, a-b; MAKI and TSUCHIYA, 1923, pp. 38-39, pl. 2, fig. 3.

Penaeopsis, affinis, DE MAN, 1911, p. 57, pl. 6, fig. 15, BALSS, 1914, p. 7; KEMP, 1915, p. 321 and 1918, p. 294; HIRUMA, 1925, pp. 33-35, fig. 5; OSADA, TANIZAKI and NAKAZAWA, 1936, p. 6, pl. 3, middle (right); YOSHIDA, 1941, p. 13, pl. 12, fig. 1.

Penaeus affinis, H. MILNE-EDWARDS 1837, p. 416; BATE, 1881, pp. 179-180, pl. 12, fig. 6; KISHINOUYE, 1900, p. 16, pl. 4, fig. 1 and pl. 7 fig. 5; LANCHESTER, 1901, p. 572.

Penaeus affinis (—? p. *monodon* FABR.), HENDERSON, 1893, p. 448.

Parapenaeus affinis, RATHBUN, 1902, p. 38.

Not: *Penaeus affinis* DE HAAN, 1850, pp. 192-193; MIERS, 1878; p. 304.

Body has many irregular depressed setose areas as shown in Figs. 125, *A*–*D*. Rostrum almost straight, slightly tilted upwards. Postrostral carina very low, reaching posterior edge of carapace, glabrous on upper surface. Adrostral, post-ocular, orbito-antennal, cervical, hepatic and branchio-cardiac grooves present. Adrostral shallow, vanishing below epigastric spine. Post-ocular clearly cut, straight, running postero-laterally. Orbito-antennal rather deep, decreasing posteriorly in width, meets with hepatic and cervical ones in front of hepatic spine. Cervical nearly straight, passing postero-dorsally, reaches about half-way toward two-thirds of dorso-median line of carapace. Hepatic somewhat C-shaped, as deep as cervical one, extending from anterior base of hepatic spine to a distance from antero-lateral margin of carapace, with sharply defined posterior (or inferior) rim along its anterior two-thirds. Branchiocardiac shallow, straight, anteriorly inclined downward Supra-orbital margin sharply defined, but not spiniform. Pterygostomian angle rounded. Epigastric spine stands at about a quarter of carapace. Pleon dorsally carinated backward to third somite, the carina of sixth somite ends in an acute spine. Sixth abdominal somite 1.3 times as long as wide, about half the length of carapace, armed with a minute spine directed rearward at postero-lateral angle. Telson tapers into a sharp point, thrice as long as wide measured at the widest region, greatly exceeded by tip of inner uropod, five-eighths the length of carapace, with a deeply cut narrow dorso-median groove, and without lateral spines (Fig. 4, *D*).

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(1) according to SCHMITT's illustration (pl. 59, fig. 1).

(2) according to KINOSHITA's figure (p. 270).

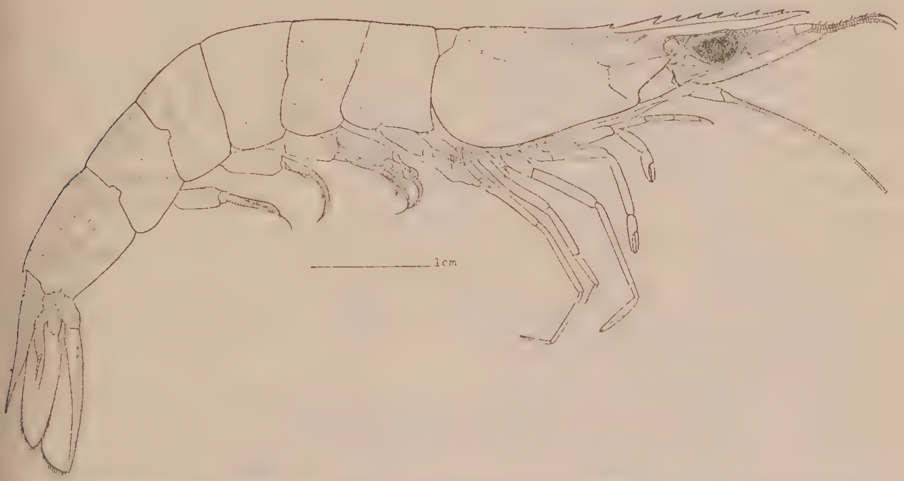

Fig. 124. *Metapenaeus affinis* (*H.* MILNE-EDWARDS), male, 76.5 mm long (18 mm in carapace-length).

Prosartema hardly extending to anterior end of cornea, does not each to far end of basal antennular segment. Stylocerite stretching as ar as middle of first joint of antennular peduncle. Antennular flagella ubequal in length, a little less than half the length of carapace in male, vhilst a third as long as carapace in female. Basicerite without spine n anterior outer edge. Scaphocerite slightly surmounts tip of antennular stalk, thrice as long as wide measured at base, gradually narrows orward by about half, with a stout disto-lateral spine which extends as ar apex of lamella.

Mandible: molar process flat on masticatory surface which is ubrectangular in outline, inner masticatory edge sharper than the other. ncisor one with a notch at distal one-third of cuting edge. Palp attains base of carpocerite; basal joint invertedly triangular in outline, as long as wide; the last one with narrowly rounded apex, remarkably convex in proximal two-thirds of outer edge, somewhat less than twice as long as broad, two and half times the length of basal one (Fig. 7, *P*). Maxillulary palp two-jointed; basal joint foliaceous, 2.5 times the width, with wavy anterior rim which has two large setae at two-thirds, the other rim has a protuberance with rounded apex near base; distal one vestigial, bluntly pointed at apex, ca. one-sixth the length of basal one. Maxilla is of Type-G_1. Endopodite of first maxilliped five-segmented ratios in length to the last article: first 1, second and third 0.3, fourth 0.8. Second maxilliped 7-jointed: proportions in length against dactylus coxa and basis 0.6, ischium 0.5, merus 1.4, carpus 0.6, propodus 1 merus twice as long as wide, dactylus minutely rounded at apex. Third maxilliped hardly reaching far end of carpocerite, relative length against dactylus: ischium 2, merus 1.6, carpus 1.24, propodus 1.2.

First pereiopod attains distal end of basicerite. Second extending beyond basicerite by about finger. Third surmounts carpocerite by dactylus, proportions in length to movable finger: ischium 1.3, meru 2.5, carpus 3.5, propodus 0.8. Fourth stretches as far as first cheliped The last reaches far end of carpocerite, proportions in length to dactylus ischium 1.4, merus 2.5, carpus 2.4, propodus 1.7.

Appendix masculina is very similar to that of *M. monoceros* an *M. intermedius*, but differs from that of the latter two species in havin the depression on apical surface of distal piece triangular in outline an larger in size (Fig. 62, *C* and *C'*).

Petasma* considerably depressed, subrectangular in outline, abou one-third as wide as long (without disto-median projections), provide with a pair of proximomedian, disto-lateral, and distomedian projection cross-section is of Type-PC_4 (Fig. 22, *C*). Ridges-*a* and *b*, well develop ed, and rather abruptly become thinner distally. Ridge-*a* directed dors medially, and ridge-*b* slightly dorso-laterally. Disto-lateral projection sharply pointed at tip, directed antero-laterally, and much exceeded b disto-median projection. Disto-median projection tubular, triangular i outline, directed anteriorly, about 1.3 times as long as wide measured base, armed with a series of short pointed setae along subterminal out margin; ventral basal margin slightly wavy, and runs almost tran versely; inner border lies nearly parallel to median line; proximo-later angle rather acute, and stretches a little beyond outer border of dist lateral projection (Fig. 31, *A* and *B*).

Thelycum* well resembles KISHINOUYE's figures even in detai (Fig. 47, *C*).

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* Metamorphosis of the organ has given in the general part of this paper.

Cardiac plate provided with a longitudinal series of 32–35 equidistant spinules (Fig. 81, *F*). Cardiac ossicle subqurdrate in outline. Pterocardiac slender, simply bar-shaped. Prezygocardiac cucumber-shaped in outline. Zygocardiac carries upper and lower longitudinal rows of teeth, of which the upper is made up of about 10 rather vestigial teeth and the lower about 14 well developed acute teeth (Fig. 81, *F*). Urocardiac broad, truncate at anterior apex, furnished with a large pointed process on each lateral edge near anterior end (Fig. 74, *F*). Prepyloric armed on each postero-lateral margin with about 8 acuminate teeth which are decidedly smaller than median tooth, and first four of which are much smaller than the rest (Fig. 74, *F* and *L*).

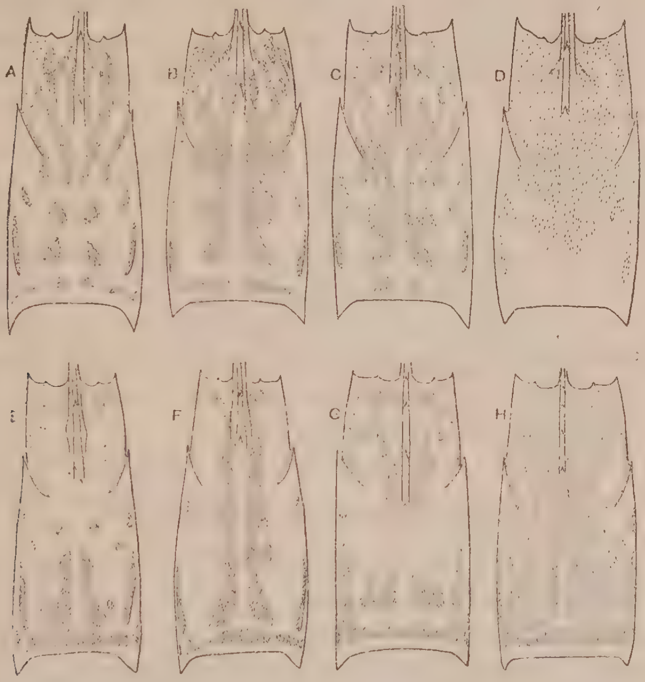

Fig. 125. Showing metamorphoses, sexual and specific differences of the depressed setose areas lying on the carapace of *Metapenaeus affinis* (*A D*), *M. joyneri* (*E* and *F*), *M. tenuipes* (*G*) and *M. lysianassa* (*H*). *A*, male, 76.3 mm long, ×2; *B*, female, 89 mm long, ×1.5; *C*, female, 48 mm long, ×3; *D*, female, 30 mm long, ×4.5; *E*, male, 109 mm long, ×1.3; *F*, female, 111.5 mm long, ×1; *G*, male, ×2; *H*, female, ×2.

The writer has examined 128 specimens (47 males and 79 females), measuring 34.0–117.5 mm long 8.9–33.0 mm in carapace-length), obtained from Tokyo (fish market); Miya, Aichi Pref.; Gokasyo-wan, Mie Pref.; bosi, Hyôgo Pref.; and Sashiki, Kumamoto Pref.

Distribution: Malabar (H. Milne-Edwards); Orissa coast, Ganjam coast, Madras, Colombo, Kuráchi (ALCOCK); Tokyo Bay to Formosa (KISHINOUYE); Java, Lombok, Bay of Bima, Saleyer (DE MAN); Singapore, Tokyo (BALSS); Rambha to Kalidai I. (Chilka Lake) (KEMP); Penang (BURKENROAD); Kurachi, Bombay, Canara, Madras (HENDERSON); Bingo, Japan (RATHBUN); Sashiki (OSADA, TANIZAKI and NAKAZAWA); Tainan (MAKI and TSUCHIYA); Ushimado and Tomo, Japan (HIRUMA); Pulau Biden, Penang (LANCHESTER); Hawaiian Islands (RATHBUN).

Note: The arrangement of the setose depressed areas of the carapace is species-specific, although the condition considerably undergoes modification with sex and age (Fig. 125, *A–D*). The areas appear hardly defined, with sparsely set setae, in younger stage, and become gradually pronounced, bearing more thickly set setae, with advance of growth. The longitulinal areas lying on each side of the dorso-median carina and the transverse ones found on each of the lateral surface near the posterior margin of the carapace are discontinuous in adult male, instead o being continuous.

The rostral spines, except epigastric one, vary from 6 to 8 in number, but mostly 7, irrespective of age and sex. Of 128 specimens, 1 have 6, 93 have 7, and 22 have 8.

The specimens dealt with well accord to the descriptions and th illustrations of the present species rendered by H. MILNE-EDWARDS BATE, HENDERSON, KISHINOUYE, ALCOCK, DE MAN and others.

The present species is similar to *M. monoceros*, *M. intermedius* an *M. joyneri*. However it is more related to the former two species i the features of petasma and thelycum.

Metapenaeus joyneri (MIERS)

(Figs. 1, *U*; 7, *S*; 22, *D*; 31, *C* and *D*; 41, *F–K*; 47, *A*; 52, *D–G*; 62, *A* and *A′*; 68, *I* and *J*; 74, *E* and *K*; 81, *G*; 125, *E* and *F*; 126).

Metapenaeus joyneri, BURKENROAD, 1934 *b* (in list) p. 7.

Metapeneus joyneri, MAKI and TSUCHIYA, 1923 pp. 42, pl. 6, fig. 2.

Penaeopsis joyneri, BALSS, 1914, p. 7; HIRUMA, pp. 422 423, fig. 3; URITA, 1926, p. 422; YU, 1935, p. 164; OSADA, TANIZAKI and NAKAZAWA, 1936, pp. 5-6, pl. 3, middle (left); YOSHIDA, 1941, pp. 14-15, fig. 6, pl. 2, fig. 3.

Penaeus joyneri, MIERS, 1880, p. 458, pl. 15, figs. 8 10; KISHINOUYE 1900, pp. 19-21, pl. 5, and pl. 7, fig. 7.

Parapenaeus joyneri, RATHBUN, 1902, p. 38.

Body with many setose shallowly depressed areas (Figs. 125, *E* an *F*, and 126). Rostrum styliform, slightly arcuate, a little more tha half the length of carapace, almost reaching to middle of intermedia article of antennular peduncle in male, extending distal rim of secon segment of the peduncle in female, armed dorsally alone with 7 teet (except epigastric tooth) of which the rearmost one is placed at a nint of carapace, penult one above frontal margin of carapace, and the foremost one at about two-thirds, post-rostral carina low, continuous to eight-ninths of carapace, slightly indent at middle of carapace in male. Postocular, orbito-antennal, cervical, hepatic and branchio-cardiac grooves present as in *M. affinis*, but the second shallower, the fourth steeper in inclination, and the last deeper than those of *M. affinis*, and the third extending half-way toward middle of carapace. All pleonic segments with dorso-median carina, but the carinae of the first three somites appear very low, that of the rest gets gradually sharper backward, and that of the sixth ends in an acute spinule. Telson closely resembles that of *M. monoceros* and *M. affinis*, about 3.7 times as long as wide, 1.2 times the length of sixth pleonic somite which is ca. 0.75 times the length of carapace. Prosartema slender, extending slightly beyond anterior margin of cornea. Stylocerite attains middle of first antennular segment. Antennular flagella different in length; upper ramus slightly longer than the other, ca. two-thirds the length of carapace in male, whilst about half as long as carapace in female. Scaphocerite hardly reaching tip of antennular peduncle in male, a little surpassing tip of the peduncle in female, and has an acute stout disto-lateral spine which is considerably exceeded by apex of lamella.

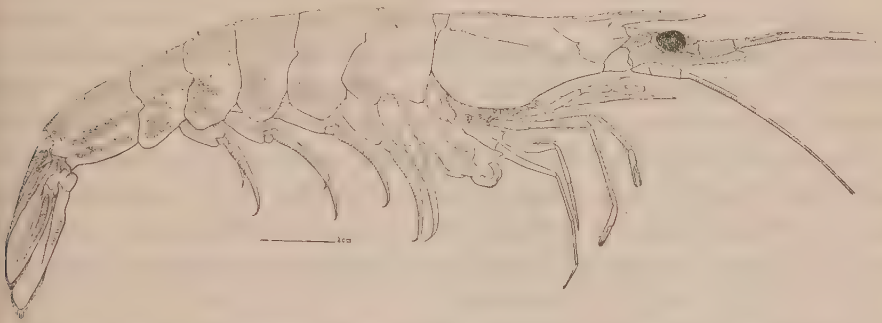

Fig. 126. *Metapenaeus joyneri* (MIERS), male, 110.6 mm in body-length (27.3 mm in carapace-length).

Mandible closely resembles that of *M. affinis;* palp stretching to base of the last antennal segment; first joint invertedly triangular in outline, as long as wide measured in the widest region; second one twice the width, 2.5 times the length of first joint (Fig. 7, *S*). Maxillula is of Type–F_2. Maxilla belongs to Type–G_1. Endopodite of first maxilliped five-segmented, proportions in length to the last segment: first 1, second 0.3, third 0.4, fourth 0.9. Second maxilliped inverted J-shaped, relative length to dactylus: coxa 0.5, basis and ischium 0.4, merus 1.2, carpus 0.6, propodus 0.7; meropodite 3 times as long as wide. Third one extends as far as carpocerite, ratios in length to dactylus: ischium and propodus 1, merus 1.5, carpus 0.9; dactylus considerably thin, bluntl pointed at apex.

Thirst pereiopod surpassing basicerite by about half of finger Second attains far end of carpocerite. Third reaches midway of intermediate joint of antennular peduncle, proportions in length to movabl finger: ischium 1.2, merus 2.7, carpus 3.4, propodus 0.9. Fourth reache to, or beyond, distal rim of basicerite. The last one slenderer than an preceding limb, stretches as far forwards as carpocerite, proportions i length to dactylus: ischium 1.5, merus 2.2, carpus 1.6, propodus 1.4.

Appendix masculina very similar to that of *M. affinis*, but th triangular depression on apical surface of distal piece is comparativel smaller (Fig. 62, *A* and *A'*).

Petasma rather depressed, subrectangular in outline, about thrice a long as wide, belonging to Type-PC_4 in cross-section (Fig. 22, *D*), furnished with proximo-median, disto-median, and disto-lateral projections a in that of *M. monoceros* (Fig. 31, *C* and *D*). Proximo-median projections about one-seventh as long as main part of petasma, suddenl expanded distally, with rounded median borders which overhang on another. Disto-lateral projections short, bluntly pointed at apex, direct slightly antero-laterally, smaller than proximo-median ones in siz Disto-median projections slender, plate-like, acute at apex, somewhat gr oved longitudinally on ventral surface, about one-third as long as ma part of petasma, directed dorsally at about three-fifths and turn pos eriorly. Ridge-*a* rather thin, relatively smaller than that of *M. mon ceros*. Ridge-*b* hardly developed.

Thelycum consists of a median elevation and a pair of later plates. Median elevation inverted racket-shaped in outline, raised som what in front of posterior border of the last thoracic sternite and e tending to anterior base of fourth pereiopods, considerably narrowed anterior half. Lateral plates arc-shaped, reaching a little behind anteri end of median elevation, rounded on distal border, abruptly broaden and directed ventro-medially in anterior half (Fig. 47, *A*).

Cardiac plate has about 23 equidistant spinules alined longitudina (Fig. 81, *G*). Cardiac, ptero-cardiac and prezygocardiac ossicles mu resemble those of *M. affinis*. Zygocardiac possesses two longitudi rows, the upper one of which is composed of 15 teeth, and the other ones which are considerably larger in size than those of upper r (Fig. 81, *G*). Urocardiac also similar to that of *M. affinis*, but round at anterior apex (Fig. 74, *E*). Prepyloric subpentagonal in dorsal aspe tapers into a bluntly pointed median tooth in posterior half, furnish along each postero-lateral edge with about 7 pointed teeth which beco gradually larger backward, the last one of which is much smaller th median tooth (Fig. 74, *E* and *K*).

The description given above mostly based on a male, 110.6 mm long (27.3 mm in carapace-length) and a female, 114.5 mm long (31.5 mm in carapace-length), the former of which was obtained from Sashiki, Kumamoto Pref. and the latter from Tokyo fish market. In addition to these, 20 males and 22 females, 55–125 mm long (13.0–33.5 mm in carapace-length) were also examined.

Locality: Tokyo (fish market); Hatazawa, Chiba Pref.; Miya, Aichi Pref.; Ushimado, Okayama Pref.; Hiroshima; and Sashiki.

Distribution: Tokyo Bay to Kyûsyû (KISHINOUYE); Ise (BALSS); Chingtao (URITA); Amoy, Chingtao, Shin-Chia-Kau, Hai-Yang-Theng (YU); Tokyo (RATHBUN); Tainan (MAKI and TSUCHIYA); Sashiki (OSADA, TANIZAKI and NAKAZAWA); Tyôsen (YOSHIDA).

Note: The number of the rostal spines ranges from 6 to 9, but is mostly 8 (see below).

Number of rostral spines	6	7	8	9
Frequency	1	18	23	2

The rostrum and antennal scale exhibit slight differences in relative length with age and sex. The rostrum of females and young males reaches to or beyond distal end of the second segment of the antennular peduncle but that of males which are at least larger than about 100 mm long hardly attain the middle of the intermediate article of the peduncle. The scales of females and young males extend a little beyond the tip of the peduncle, on the other hand, those of such larger males given above hardly attain the extremity of the peduncle.

Remarkably enough, the setose depressed areas of the carapace apear sexually dimorphic as shown in Fig. 125, *E* and *F*, besides the copulatory organs, second pleonic appendages and the pleura of the first abdominal segment (KISHINOUYE, *op. cit.;* p. 20).

The basial spines of the third pereiopods are enormously developed, extending to the half-way of the meropodite and have a spinule directed backward near the extremity in full grown male as pointed out by KISHINOYE (*op. cit.* pp. 19–20). However they appear simply acicular in young specimens, and become curved in subterminal protion reaching the distal end of the ischiopodite in specimens about 80 mm long.

Metamorphoces of petasma (Fig. 40, *F–K*), thelycum (Fig. 52, *D* and *G*) and appendix masculina (Fig. 68, *I* and *J*) were dealt with already in general part of this paper.

The present specimens at the author's disposal well agree with the descriptions and figures given by MIERS, KISHINOUYE, YU and others.

The present species is closely related to *M. monoceros* and *M. affinis*, but nearer to the former than to the latter, especially in the following respects, viz., (1) shape of rostrum; (2) all pleonic somites (except telson) dorsally carinated; (3) antennular flagella more than half the length o carapace; (4) prosartema reaching to or beyond anterior margin of cornea; (5) longer carpocerite; and (6) cardiac plate bearing less numbe of spinules. The feature common to both the present species and M *affinis* is only that the first pereiopods are unispinose. It is interestin that the setose depressed areas of body-surface of the present prawn ar found intermediate in feature between those of *M. monoceros* and M *affinis.*

Metapenaeus tenuipes sp. nov.

(Figs. 7, *R*; 22, *B*; 31, *G* and *H*; 62, *B* and *B′*; 74, *N* and *T*; 81, *H*; 125, *G*; 127).

Shell with many indent irregular setose areas as in *M. joyner* (Figs. 125, *G* and 127). Rostrum styliform, almost horizontally straigh reaching a little beyond distal rim of first segment of antennular pedun cle, somewhat more than half the length of carapace, armed above onl with 5 subequidistant teeth (except epigastric tooth), rearmost toot inserted at ninth of carapace, penult one slightly behind post-orbita edge, and the foremost at midway of the rostrum. Epigastric, antenna and hepatic spines present, the first of which is smaller than any ros ral spine, and stands more or less in front of one-third of carapace; th second is the largest of all; and the last subequal to epigastric one i size. Postrostral carina extends to about middle of carapace, a litt triangularly elevated with peak at about a ninth of carapace. Ant gastric groove not recognizable. Orbito-antennal one hardly marke Cervical one clearly cut with well-defined posterior edge, and straigh extending half-way toward middle of carapace. Hepatic one incomplet with only almost straight anterior half which is as deep as cervical on with well-defined posterior (or inferior) margin, tilted antero-ventrall commencing near antero-ventral base of hepatic spine and reaching little behind antero-lateral margin of carapace. Branchio-cardiac on shallower than cervical and hepatic ones. Supra-orbital angle we defined, but not spiniform. Pterygostomian angle rounded. Abdome dorsally carinated excluding second and third segments which are dors ly rounded; the carina is rather broad and very low with glabrous u per surface in first segment, rather sharp in fourth and fifth, but pr minent ending in an acuminate, posteriorly directed spinule in sixt Telson tapering into sharply pointed tip, with a deeply cut mid-dors groove, without lateral spines, a little less than four times as long a wide, subequal to sixth pleonic somite in length, two-thirds the lengt of carapace, greatly exceeded by apex of inner uropod.

Eye rather large, a quarter the length of carapace in longer diam ter of cornea. Prosartema extends as far as eye. Stylocerite attai somewhat behind middle of first joint of antennular stalk. Antennular peduncle with 3 segments, ratios in length to third segment: first 4, second 2. Antennular flagella different in length; upper ramus about 0.8 times as long as carapace, lower one somewhat shorter and thicker than the other. Basicerite devoid of spine on antero-outer edge. Scaphocerite tapers by about half, thrice as long as wide measured at base, reaching tip of antennular peduncle, furnished at disto-lateral angle with a sharp stout spine which is well surmounted by apex of lamella. Carpocerite stretching as far as anterior rim of cornea, about three times as long as wide.

Mandible: Molar process flat on masticatory surface, sharply pointed at postero-median angle. Incisor one with sharp cutting border which has a notch near anterior end. Palp similar to that of *M. joyneri*, reaching inner base of carpocerite; basal segment invertedly triangular, as long as wide measured at the widest region; the distal twice the width, 2.3 times the length of basal joint (Fig. 7, *R*). Maxillulary palp foliaceous, two-segmented; the first 2.3 times as long as broad measured near base, anterior margin has proximal larger and distal smaller protuberances, each of which is rounded at apex and the distal one provided with a spinous setae, posterior margin slightly convex bearing a rather small protuberance with rounded apex near base; the second narrowly rounded at tip, a fifth the length of first one. Endopodite of first maxilliped five-segmented, proportions in length to the last joint: first 1.1, second 0.3, third 0.5, fourth 0.9. Second maxilliped inverted J-shaped, proportions in length to dactylus: coxa, basis and ischium 0.5, merus 1.25, carpus 0.6, propodus 0.7; meropodite a little less than thrice as long as wide. Third maxilliped reaching as far as carpocerite, ratios

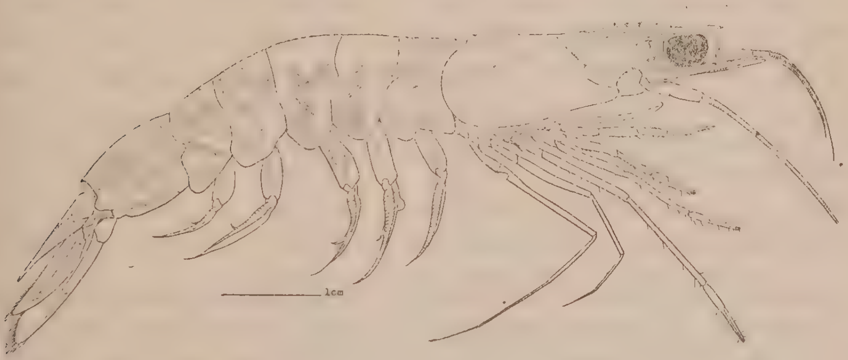

Fig. 127. *Metapenaeus tenuipes* sp. nov., male, 75 mm long.

in length to the last segment: ischium 1.4, merus 1.6, carpus 1.2, propodus 1.1.

First pereiopod extending far end of carpocerite. Second one hardly reaches apex of antennal scale. Third one surpassing distal end of antennal scale by finger, about 11 times as long as wide in meropodite. Fourth one hardly reaches far end of second segment of antennular peduncle. The last surmounts tip of scaphocerite by about dactylus, much slenderer than any preceding ones, meropodite deeply notched on posterior edge close to proximal end. A basial spine present on each pereiopod from first to third, that to the third simply acicular, reaching about middle of ischiopodite. Dimensions and proportions of each segment of each leg in length to dactylus are given in table 43.

Table 43. Dimensions in mm and proportions in brackets

Items	Ischium	Merus	Carpus	Propodus	Dactylus
First leg	3.0 (0.85)	6.0 (1.71)	5.0 (1.42)	2.0 (0.57)	3.5
Second „	3.2 (0.80)	8.2 (2.05)	8.5 (2.12)	2.5 (0.62)	4.0
Third „	3.2 (0.80)	10.0 (2.50)	12.3 (3.07)	3.0 (0.75)	4.0
Fourth „	3.1 (0.79)	8.8 (2.25)	7.3 (1.87)	4.9 (1.25)	3.9
Fifth „	4.0 (0.78)	12.0 (2.35)	6.5 (1.3)	8.2 (1.6)	5.1

Appendix masculina is of Type-O_5, very closely resembles that o *M. affinis* and *M. joyneri*, but nearer to that of the latter in conditio of the triangular depression lying on apical surface of distal piece (Fig 62, *B* and *B*′).

Petasma well-calcified, rectangular in outline, thrice the width as i that of *M. joyneri*, disto-median projetions comparatively shorter tha disto-lateral ones which bear shaper apex (Figs. 22, *B*, and 31, *G* an *H*).

Cardiac plate with 24 equidistant spinules alined longitudinall Zygocardiac ossicle has two rows of rather closely set teeth, upper o of which is made up of 11 teeth with rounded apex, and the other co sists of 13 acuminate ones (Fig. 81, *H*). Urocardiac rather broad, som what more than twice as long as wide measured at mid-way, trunca at anterior end, expanded sidewise with bluntly pointed apex near ante rior edge (Fig. 74, *N*). Prepyloric one pentagonal in upper aspect, na rows to a bluntly pointed large median tooth, provided along each post lateral margin with 8 teeth which are much smaller than median on rounded at apex (Fig. 74, *N* and *T*).

The above mentioned description is based on a male, 75 mm lon

(18.5 mm in carapace-length), obtained from South coast of Borneo by Assistant Prof. S. SAITO.

The present species is very similar to *M. joyneri* in many respects. But it seems to be sufficiently distinct from the latter. The differences found between them are given below (Table 44).

Table 44.

Items	Present species	*M. joyneri*
1. Rostrum	with 5 teeth	with 6-9 teeth (mostly 8)
2. Postrostral carina	extends to about middle of carapace; a trifle elevated in front of epigastric spine	attain eight-ninth of carapace; not lifted in front of epigastric spine
3. Post-ocular groove	absent	present
4. Dorso-median carina of pleon	absent in second and third pleonic somite	present on all somites from first to sixth
5. Upper antennular flagellum	0.8 times as long as carapace	0.66 times as long as carapace
6. Second leg	hardly reaches apex of scaphocerite	reaching far end of carpocerite
7. Third leg	surpassing scaphocerite by finger	attains midway of second segment of antennular peduncle
8. Fourth leg	hardly reaching far end of second segment of antennular peduncle	reaches to or beyond distal rim of basicerite
9. Fifth leg	surmounts tip of scaphocerite by dactylus	reaches to or beyond far end of carpocerite
10. Basial spine of third leg	simply acicular, extending middle of ischium	with a spinule directed backward in subterminal portion, reaching midway of merus
11. Petasma	disto-median projection shorter, disto-lateral one longer with sharply pointed apex	disto-median projection longer, disto-lateral one shorter with blunt apex

Metapenaeus brevicornis (H. MILNE-EDWARD)

(Figs. 7, *U*; 47, *F*; 74, *P* and *V*; 81, *M*; 128; 129, *A-D*)

Metapeneus brevicornis ALCOCK, 1906, pp. 22-23, pl. 4, fig. 10, 10 *a-b*.
Penaeopsis brevicornis, KEMP, 1918, pp. 294-295.
Penaeus brevicornis, H. MILNE-EDWARDS, 1837, p. 417; BATE, 1881, p. 180, pl. 11, fig. 3; HENDERSON, 1893, p. 450; DE MAN, 1897, p. 681; LANCHESTER, 1901, p. 571.
Metapenaeus avirostris, NOBILI, 1903, p. 2.
Penaeopsis avirostris, BALSS, 1914, p. 10.

Penaeus avirostris, DANA, 1852, p. 603, pl. 40, fig. 3; HELLER, 1865, p. 123; MIERS 1880, p. 457.
Penaeus sp. LANCHESTER, 1901, p. 571, pl. 34, fig. 7.

Shell glabrous. Postrostral carina gets gradually weaker backward and fade out somewhat in front of posterior edge of carapace. Antegastric and orbito-antennal grooves hardly marked. Cervical one rather deep with sharp lower (or posterior) rim, straight extending postero-dorsally to reach about a third toward two-thirds of dorso-median line of carapace. Hepatic one only defined in anterior half more or less curved with lower edge as sharp as that of the cervical, running from a point somewhat antero-ventral to base of hepatic spine toward a point a little posterior to pterygostomian edge. Branchio-cardiac groove rather marked. Epigastric, antennal, and hepatic spines present, the first subequal to the foremost rostral tooth in size, inserted at a little forward to a third of carapace, the second as large as epigastric one, and the third larger than other two, placed a trifle below antennal spine and a little posterior to epigastric one. Supra-orbital angle minutely pointed Pterygostomian angle rounded. Abdomen dorsally carinated backward to two-thirds of fourth somite, the carina of sixth somite very prominent, ending in a sharp spinule; sixth somite has weakly marked cicatrices, without a spinule at postero-inferior angle, 1.2 times as long a wide, about half the length of carapace. Telson sharply pointed at tip devoid of lateral spines, much surpassed by apex of inner uropods (Fig 128).

Eye rather large, a fifth the length of carapace in longer diamete of cornea. Prosartema extending as far as distal rim of eye. Stylocerit short, reaching a trifle behind half-way of basal antennular segment Antennular stalk two-thirds the length of carapace, more or less surpassing tip of rostrum, relative lengths to the last article: first 5, second 2 Antennular flagella different in length; upper ramus somewhat longe than the other, a little less than half the length of carapace. Basicerit unarmed on antero-lateral edge. Scaphocerite reaching slightly beyon tip of antennular peduncle, 2.5 times as long as wide measured at bas narrowed anteriorly by about half, with a disto-lateral spine which well-exceeded by apex of lamalla. Carpocerite extending as far forwa as distal margin of eye; thrice as long as wide.

Mandible: molar process concave on masticatory surface, out masticatory edge considerably produced inwards, as sharp as distal rim of incisor process. Incisor one slightly wavy on cutting edge, without notch. Palp attains base of carpocerite; basal joint invertedly triangula in outline, as long as wide measured at the broadest region; distal on narrowly rounded at apex, greatly convex in proximal half of outer rim twice the width, 2.5 times the length of basal one (Fig. 7, *U*). Maxi lulary palp closely resembles that of *M. tenuipes*, distal joint about a quarter the length of the other. Endopodite of first maxilliped 5-jointed, ratios in length to the last segment: first 1.1, second 0.3, third 0.4, fourth 0.7. Second maxilliped normal in shape, proportions in length to dactylus: coxa, basis and ischium 0.5, merus 1.2, carpus and propodus 0.6; meropodite thrice the breadth. Third one hardly reaching far end of carpocerite, ratios in length to dactylus ischium and merus 1.2, carpus and propodus 1.1.

First pereiopod surpassing basicerite by finger, armed with both basial and ischial spines; movable finger 1.6 times the length of palm. Second one reaches far end of first segment of antennular peduncle, with a basial spine only; movable finger one and half times as long as palm. Third extending to tip of antennular stalk, also bearing a basial spine; proportions in length to movable finger; ischium 1, merus 2.2, carpus 3.2, palm 0.8, merus 9.2 times the width. Last two ones slenderer than chelipeds. Fourth reaching a trifle behind distal edge of carpocerite; coxopodite furnished on inner side with a lamellar expansion which comes into contact with lateral margin of median plate of thelycum. Fifth surmounts apex of scaphocerite by dactylus, ratios in length to dactylus: ischium 0.8, merus 2.3, carpus 2.2. propodus 1.9.

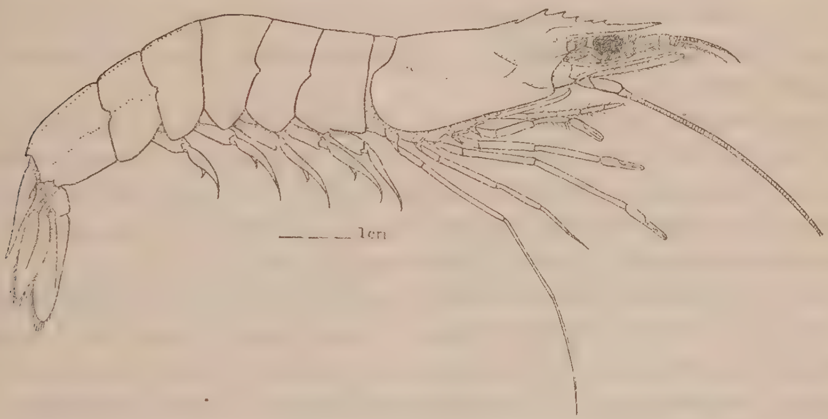

Fig. 128. *Metapenaeus brevicornis* (H. MILNE-EDWARDS), female, 86.8 mm long.

Thelycum consists of a median and a pair of lateral plates. Median plate rather broad, panduriform, occupies about 50% of ultimate thoracic sternite in width, minutely pointed at apex, about 1.3 times as long as wide measured at the widest region, longitudinally depressed at a considerable degree on ventral surface, extending from middle of the last thoracic sternite to the level transverse through anterior base of fourth pereiopods. Lateral lobes inverted C-shaped, much narrower (ca. half) than median plate; enterior ends attain half-way of median plate, poste rior ones separated from each other (fig. 47, *F*).

White conjoined pads attached on thelycum after copulation, sub circular in outline with irregular margins, convex on outer surface (Fig 129, *D*).

Cardiac plate has 18–21 spinules alined longitudinally (Fig. 81, *M* Zygocardiac ossicle provided with two longitudinal rows, upper one o which is composed of about 11 rather rudimentary teeth, and lower on about 12 well-developed pointed ones (Fig. 81, *M*). Urocardiac wit truncate anterior margin and a large pointed projection on each latera border near anterior extremity (Fig. 74, *P*). Prepyloric ends in a larg median tooth with rounded apex, armed on either postero-lateral edg with about 6 teeth which become gradually larger backward, but smal ler than median one even in the hindmost one (Fig. 74, *P* and *V*).

The foregoing description is made from a female, 86.8 mm long (22. mm in carapace-length) obtained from Bangkok. Other 13 females, 58 107 mm long (15.0–29.3 mm in carapace-length) from Bangkok an Singapore were also examined.

Distribution: Coast of India (H. Milne-Edwards); Karachi, Ca cutta, off Ganjan (23 fathomes), G. of Martaban, Penang, Madra (Alcock); Kurachi, Calcatta (Hendersen); Patani (Lanchester) Ceylon (Heller); Borneo (Miers); Buntal (Nobili); Singapore (Dana Balss, Burkenroad); Patany, Tale sap. (Kemp).

Note: The rostrum demonstrates an age variation, becoming longe with advance of age. In a young, 58 mm long (15 mm in carapac length) it appears considerably short and closely related to that of *M lysianassa* De Man, viz., it attains a trifle behind distal margin of th first segment of antennular peduncle, somewhat less than half the lengt of carapace. When the animal attains a length of 84 mm (22 mm i carapace-length) the rostrum is surpassing the distal edge of the firs segment by a quarter of its length, about half as long as carapace. I an adult female, 107 mm long (29.3 mm in carapace-length) the rostru extends beyond the margin of the peduncle by about a third of it length, ca. 0.6 times the length of the carapace (Fig. 129, *A–C*).

The rostral spines are 5 to 7 (including epigastric one), mostly 6 i number. Of 14 specimens, 12 have 6 ones. Posterior 3 of the spine are always found on the carapace, the antepenult one is situated abov or a little behind the post-orbital edge of the carapace, and the foremos one about middle or slightly anterior to middle of the cornea.

Our specimens exactly agree with the accounts and figures give by H. Milne-Edwards, Dana, and Alcock except Alcock's Fig. 10 from which they differ as follows:—the post-rostral carina is more lifte than in his figure as is the case with Kemp's specimens.

Henderson (*op. cit.* p. 450) mentions "the first three pairs of legs are unispinose at the base," however, the first pereiopods of our specimens are bispinose. The ischial spines of these pereiopods are very minute, much smaller in size than those of the basial ones of the same legs. Thus it seems to the write that the ischial ones are probably overlooked by Henderson.

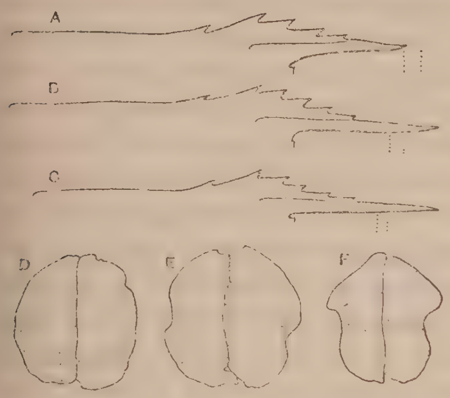

Fig. 129. Rostrum of female of *Metapenaeus brevicornis* (H. Milne-Edwards), especially showing age-variation in length (*A–C*) and white conjoined pads found on thelycum after copulation (*D–F*). *A*, 58 mm long (15 mm in carapace-length), ×2.5; *B*, 84 mm long (22 mm in carapace-length), ×2; *C*, 107 mm long (29.3 mm in carapace-length), ×ca. 1.1; *D*, *Metapenaeus brevicornis*, ×6; *E*, *Metapenaeus lysianassa*, ×7.5; *F*, *Metapenaeus spinulatus* sp. nov, ×7.5. Anterior broken lines showing distal end of basal segment of antennular peduncle; posterior ones distal margin of cornea.

The young specimens at our disposal agree well with the description of *Penaeus* sp. of Lanchester (*op. cit.*, p. 571). Hence, his specimens should be referred to the present species.

Penaeopsis sp. of De Man (1911, pp. 60–61) was identified with *Penaeopsis avirostris* (=*Penaeus avirostris* Dana) by Balss (1914, p. 10). The present specimens, however, stand at variance with the description of *Penaeopsis* sp. of De Man at least in the points given below.

Items	Present specimens	*Penaeopsis* sp. De Man
1. First leg	bispinose	unispinose
2. Fifth leg	supassing apex of antennal scale by dactylus	reaching far end of carpocerite
3. Lateral plate of thelycum	separated posteriorly by a distance	quite posteriorly united with one another

Such being the case, the writer is inclined to consider that the specimens described by De Man as *Penaeopsis* sp. are probably referable to another species.

Metapenaeus spinulatus sp. nov.

(Figs. 7, *T*; 47, *G*; 74, *M* and *S*; 81, *K*; 129, *F*; 130)

Penaeopsis (*Metapenaeus*) *brevicornis*, Burkenroad, 1934 *b*, pp. 33–35.

Shell glabrous. Rostrum styliform, horizontally straight, attains distal end of intermediate antennular segment, unarmed in distal half of upper and entire lower borders, with a well marked lateral carina which arises below penult rostral tooth, and curves upward and forward and reaches to a little in front of the foremost rostral tooth; upper border continuous to six-sevenths of carapace, triangularly elevated with peak at a seventh of carapace, but gets gradually inconspicous posterior to middle of carapace, armed with 7 teeth, anterior 6 of which are set equidistantly, the hindmost one stands at about a third of carapace penult one at one-eighth, and antepenult one slightly behind post-orbital margin. Carapace very similar to that of *M. brevicornis*, but post-ocular groove a little more pronounced. Abdomen dorsally carinated backward to one-third of fourth somite, with cicatrices on fifth and sixth somites minutely pointed at postero-median edge of the sixth. Telson tapering into an acute tip, armed with two pairs of lateral spinules near apex greatly exceeded by tip of inner uropods which are much shorter than outer ones, two-thirds the length of carapace (Fig. 130).

Eye one-fifth the length of carapace in longer diameter. Prosartema extending as far as anterior rim of eye. Stylocerite extends to mid-way of basal antennular segment. Antennular stalk ca. 70% of carapace length, basal article 1.5 times the length of the second which is thric the length of the last. Antennular flagella about two-thirds as long a carapace. Basicerite without spine on antero-lateral edge. Antenna scale similar to that of *M. brevicornis* in general configuration, some what surpassing tip of antennular peduncle. Carpocerite extends as fa as eye, three times the width.

Mandible: molar process almost flat on masticatory surface, wit sharp inner masticatory rim. Incisor one has a notch near anterior en of cutting edge. Palp reaches proximal end of carpocerite; basal seg ment invertedly triangular in outline; distal one tapering with rounde apex, twice as long as wide, a little less than 2.5 times the length o basal one (Fig. 7, *T*). Maxillulary palp two-jointed; first joint foli aceous, with proximal larger and distal smaller swellings on anterio border, the latter of which bears a spinous seta on apex, and carrie many short setae alined longitudinally in subterminal portion near poste rior edge; second one very smaller and slender, somewhat narrow distally, rounded at apex, about a quarter the length of basal on Endopodite of first maxilliped segmented into five, proportions in lengt to the last segment: first 1, second 0.3, third 0.5, fourth 0.8. Secon maxilliped normal in shape, ratios in length to dactylus: coxa and basi 0.5, ischium 0,4, meus 1.25, carpus 0.6, propodus 0.7; meropodite tw and half times as long as wide. Third maxilliped reaches slightl beyond far end of carpocerite, proportions in length to dactylus ischium 1.5; merus 1.8, carpus and propodus 1.3.

First cheliped surmounting carpocerite by finger, with a basial an ischial spines, the latter of which is very small, relative length to movable finger: ischium 0.7, merus 1.6, carpus and propodus 1.3, palm 0.5. Second attains distal end of intermediate antennular segment, with an ischial spine, proportion in length to movable finger: ischium 0.9, merus 2, carps 2.3, palm 0.6. Third reaches beyond apex of scaphocerite by finger, with an ischial spine, a little slenderer than the first, but as thick as the second, proportions in length to mobile finger: ischium 0.7, merus 1.6, carpus 2.6, palm 0.65; merus about 14 times the width. Fourth surpassing carpocerste by dactylus, without coxal plate, proportions in length to the last joint: ischium 1.4, merus 3.3, carpus 2.9, propodus 2. Fifth stretches beyond scaphocerite by dactylus and major part of propodus; merus 3.8 times the length of ischium, slightly longer than carpus.

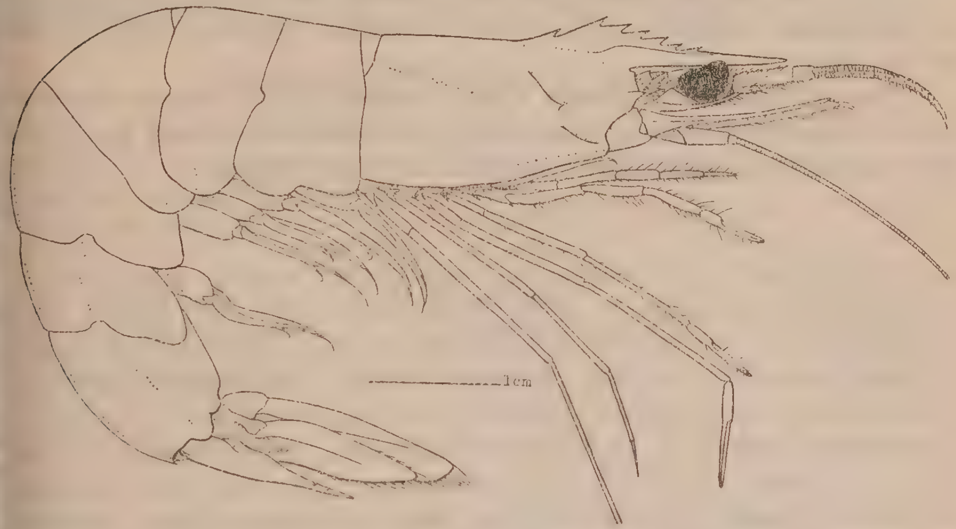

Fig. 130. *Metapenaeus spinulatus*, sp. nov., female, 74.3 mm long.

Thelycum consists of a median and two lateral plates as in *M. brevicornis*, and an inconspicuous conical median boss; median plate occupying about 30% of sternite between fourth pereiopods in width, and much smaller than lateral plates; lateral one attains anterior one-third of median plate, provided with a prominent carina running from antero-median angle to postero-lateral one; conical median boss lies on a level transverse through anterior bases of fifth limbs (Fig. 47, *G*). White conjoined pads found on thelycum after copulation subpentagonal in outline with narrowed apex directed anteriorly, furnished with a protuberance with rounded apex at anterior one-third, one and half times as long as wide (Fig. 129, *F*).

Cardiac plate with 24 equidistant spinules arranged in a longitudinal row (Fig. 81, *K*). Zygocardiac ossicle has two longitudinal series upper of which is made up of 6 rather vestigial closely set teeth, th other 9–12 ones (Fig. 81, *K*). Urocardiac with slightly concave anterio border and a pair of large pointed lateral processes near anterior en (Fig. 74, *M*). Prepyloric narrowed to a large median tooth with rounde apex in posterior half, furnished along each postero-lateral margin wit about 6 bluntly pointed teeth which gradually increase in size posteriorl and much smaller than median tooth even in the last one (Fig. 74, *M* and *S*).

Holotype: female, 74.3 mm long (19 mm in carapace-length).

Paratype: two females, 88.4 and 92.5 mm long respectively (23. and 23.5 mm in carapace-length).

All specimens were obtained from Bankok.

Note: In the two paratypes, the rostrum extends as far as tip o the antennular peduncle, with 7 teeth in smaller specimen and 8 one in the other.

The present species is very closaly related to *Metapenaeus brevicor* *nis* (H. Milne-Edwards). But it may be distinguished from the latte by a number of characteristics peculiar to it as follows:—

Items	Present species	*M. brevicornis*
1. Rostrum	with 7 or 8 teeth	with 5-7 teeth
2. Telson	armed with two pairs of lateral spinules	without lateral spinules
3. Antennular peduncle	second joint as long as the third	twice as long as the thir
4. Antennular flagella	two-thirds the length of carapace	half the length of carapa
5. First legs	surpassing carpocerite by finger	surpassing basicerite finger
6. Second legs	attain distal end of second antennular segment; finger 1.7 times the length of palm	attain far end of first a tennular segment, finger times the length of palm
7. Third legs	surpassing antennal scale by finger	reaching apex of antenn lar peduncle
8. Fourth legs	reaching beyond carpocerite by dactylus, without coxal plates	reaching a little behind d tal rim of carapace, wi coxal plates
9. Fifth legs	surpassing antennal scale by major part of propodus and dactylus	surpassing antennal sca by dactylus only

10. Thelycum	median plate smaller than lateral ones occupying ca. 30% of sternite between fourth legs in width; each lateral plate with a prominent ridge running postero-laterally on ventral surface; a median boss present on sternite between fifth legs	median plate much larger than lateral ones, occupying ca. 50% of sternite between fourth legs in width; lateral plate without ridge on ventral surface; a median boss absent on sternite between fifth legs
11. white conjoined pads lying on thelycum after copulation	subpantagonal in outline	subcircular in outline

The specimens identified with *Penaeopsis* (*Metapenaeus*) *brevicornis* (H. MILNE-EDWARDS) by BURKENROAD (*op. cit.* pp. 33–35) are probably referable to the present species, since his specimens have, according to his description (*op. cit.* p. 34), spines on lateral margins of the telson.

Metapenaeus lysianassa (DE MAN)

(Figs. 7, *V*; 47, *H*; 74, *O* and *U*; 81, *I*; 125, *H*; 129, *E*; 131)

Metapeneus lysianassa, ALCOCK, 1906, pp. 23–24, pl. 4, figs. 11 and 11 *a–c*.
Penaeopsis lysianassa, BURKENROAD, 1934, p. 36.
Penaeus lysianassa, DE MAN, 1888, pp. 290–295, pl. 19, figs. 1–11.

Body with many setose depressed irregular areas resembling those of *M. joyneri* (Fig. 131). Rostrum furnished on each side with a lateral carina which extends below antepenult post-rostral spine. The last post-rostral spine stands at a third of carapace. Post-ocular groove hardly recognizable. Orbito-antennal one illdefined. Cervical one well-marked, hirsute, straight running postero-dorsally, attains mid-way toward two-thirds of median line of carapace. Supra-orbital angle defined, but not spiniform. Pterygostomian angle rounded. Telson tapering with an acute apex, as long as sixth pleonic somite, two-thirds the length of carapace, armed with 18–20 short setae along each subterminal lateral edge.

Prosartema somewhat surpassing anterior margin of eye. Stylocerite extends as far as middle of basal antennular joint. Antennular peduncle hairy; intermediate segment 2.5 times the length of the third. Antennular flagella different in length; upper ramus a little longer than the other, as long as carapace. Basicerite with no spine on disto-lateral border. Antennal scale stretches more or less beyond tip of antennular peduncle, with a disto-lateral spine which is well exceeded by distal edge of lamella. Carpocerite attains a third of antennal scale, a little more than thrice the width.

Mandible: molar process slightly indent on masticatory surface, with a sharp projection at postero-median angle of masticatory edg Incisor one with a notch near anterior end of cutting edge. Pal closely resembles that of *M. brevicornis;* distal segment somewhat les than twice as long as wide, about twice the length of basal one (Fig. 7 *V*). Maxillulary palp very similar to that of *M. spinulatus* in genera aspect. Endopodite of first maxilliped five-jointed, proportions in lengt to the last joint: first 1.1, second 0.3, third 0.4, and fourth 0.9. Secon curved pediform, meropodite two and half times the width, 1.2 times th length of dactylus. Outer maxilliped reaches beyond carpocerite b dactylus, proportions in length against ultimate joint: ischium and propodus 1.2, merus 2, carpus 1.3.

First pereiopod attains far end of carpocerite, proportions in lengt to movable finger: ischium 1.1, merus 2, carpus 1.5, palm 0.6. Secon reaching distal end of penult antennular joint. Third stretches slightl beyond scaphocerite, relative dimensions to mobile finger: ischium an palm 1, merus 2.9, carpus 3.5. Fourth extending as far as first on Fifth surmounts antennal scale by half of dactylus.

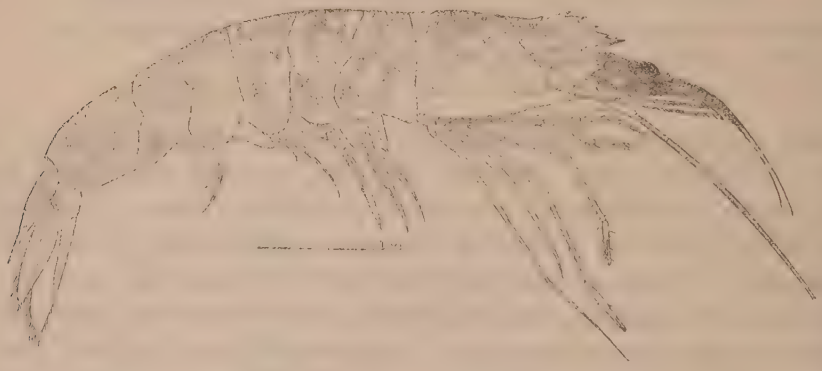

Fig. 131. *Metapenaeus lysianassa* (DE MAN), female, 64 mm long.

Thelycum consists of a median and a pair of lateral plates, each which is subequal in size and suboval in outline; median plate cove almost entire sternite between fourth periopods, medially more or le depressed, ranging from about middle of penult thoracic sternite to th of ultimate one; lateral ones flattish, placed antero-laterally, extending little behind posterior base of fourth pereiopods (Fig. 47. *H*). Wh conjoined pads found on thelycum after copulation cirular in outline is the case with *M. brevicornis* (Fig. 129, *E*).

Cardiac plate has 10–12 equidistant spinules alined longitudinal Zygocardiac ossicle with two longitudinal series, each of which is ma up of about 10 closely set acuminate teeth, but the teeth of upper seri more or less smaller than those of the other (Fig. 81, *I*). Urocardi closely resembles that of *M. brevicornis* in general feature (Fig. 74, *O*). Prepyloric narrowed to a large pointed median tooth; each postero-lateral margin with 6–7 slender acute teeth which become gradually larger backward, but each of which is much smaller than the median (Fig. 74, *O* and *U*).

Described from a female, 64 mm long (15.7 mm in carapace-length). Other two females, 16.0 mm and 16.2 mm in carapace-length, both of which are mutilated in tip of telson and the latter in antennular flagella, were also examined. All of them were obtained from Singapore.

Distribution: Singapore, Penang, and Selangor (BURKENROAD); Mergui Archipelago (DE MAN); Mergui, Orissa coast, G. of Martaban (20 fathoms), Sandheads, R. Hooghly (ALCOCK).

Note: Our specimens agree with DE MAN's brief original description and illustrations in all important characters, although the following respects are found discrepant.

Items	Present specimens	DE MAN's *M. lysianassa*
1. Supra-orbital angle	defined, but not spiniform	with a small tooth
2. Telson	has 18–20 short spinules along subterminal lateral edge	"quite unarmed and not spiniferous"
3. Third maxilliped	reaches beyond carpocerite by dactylus	reaches somewhat behind far end of carpocerite
4. First leg	finger 1.7 times as long as palm	finger a little longer than palm
5. Third leg	reaches slightly beyond scaphocerite	reaches nearly distal end of second antennular stalk.
6. Fifth leg	surpassing antennal scale by half of dactylus	a little surpassing distal end of carpocerite

However, such differences, excepting the lateral setae of the telson which were probably overlooked by DE MAN, may be admited as an intraspecific variation.

Genus *Trachypenaeopsis*, BURKENROAD

Trachypenaeopsis, BURKENROAD, 1934 *b*, pp. 40–41.

At present the genus includes two species: *Trachypenaeopsis mobilispinis* (RATHBUN), which is the genotype and an Atlantic form, and *Trachypenaeopsis richtersii* (MIERS).

Trachypenaeopsis richtersii (MIERS)

(Figs. 8, *I*, 47, *E* : 74, *R* and *X*; 81, *J*; 132; 133, *A–E*)

Trachypenaeopsis richtersii, BURKENROAD, 1934, p. 40.
Penaeus richtersii, MIERS, 1884, pp. 564–565, pl. 52, Fig. A.
Penaeopsis richtersii, DE MAN, 1911, pp. 64–65, pl. 7, Fig. 19 *a–c*.
Metapenaeus richtersii, RATHBUN, 1906, p. 904, pl. 20, Fig. 2, text-fig. 57.

Rostrum a third the length of carapace. Antegastric groove rath defined. Cervical one clearly cut, nearly straight, attains about ha way toward middle of carapace. Hepatic one sigmoid, commencing little behind hepatic spine, and attains a trifle behind pterygostomi. angle. Abdomen dorsally carinated in fifth and sixth somites only as MIERS's specimens, the carina of the latter ends in an acute spinu Sixth pleonic somite 1.6–1.7 times as long as wide measured at midd two-thirds the length of carapace. Telson agrees well with MIE Fig. *A*′, about 4 times as long as wide measured in the widest reg armed with 3 pairs of lateral spines, first of which are placed at t ninths, the second at middle, and the last at three-quarters; the sp of the first two pairs are movable and those of the last inmova obliquely jointed at a third, 2–3 times larger than other ones, excee by distal about 10% of the apparatus, extending as far as tip of in uropods (Fig. 133, *A*).

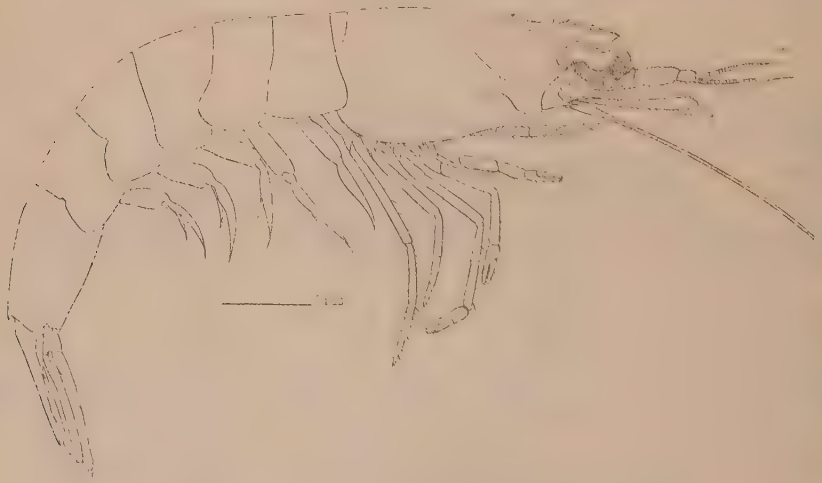

Fig. 132. *Trachypenaeopsis richtersii* (MIERS), female, 42.5 mm long.

Eye a trifle less than a third the length of carapace in longer meter of cornea. Prosartema falls somewhat short of distal margin eye. Stylocerite reaching half-way of basal antennular segment. An nular flagella different in length, upper ramus somewhat shorter than lower one which measures half times as long as carapace. Basicerite has a prominent acicular spine at disto-lateral lower angle. Scaphocerite slightly surpassing tip of antennular peduncle, provided with an antero-lateral spine which is a little surmounted by apex of lamella.

Mandible: molar process somewhat concave on masticatory surface, with somewhat produced sharp inner masticatory edge which ends in an acuminate projection at postero-median angle. Incisor one with a notch near anterior end of cutting edge. Palp attains base of carpocerite, basal joint subtriangular in outline as long as wide; distal one rather abruptly pointed at apex, about 1.4 times as long as wide, 1.8 times the length of basal one (Fig. 8, *I*). Maxillulary palp two-segmented; basal segment foliaceous, 2.8 times the width measured near base, suddenly narrowed toward the end, with a deep notch at three-fifths, and a spinous seta at three-fourths of anterior border, bearing several equidistant setae along subterminal posterior edge. (Fig. 133, *B*). Maxilla is of Type–G_1 (Fig. 133, *C*). First maxilliped well-developed; endopodite five-jointed, proportions in length to the last joint: first 2.9, second 0.8, third 1.2, fourth 2.1; exopodite narrowly rounded at apex, 5 times the width measured at middle (Fig. 133, *D*). Second maxilliped inverted J-shaped; meropodite 2.3 times as long as wide, 1.5 times as long as dactylus. Third one rather thick, proportions in length to dactylus: coxa 0.7, basis 0.5, ischium 1.3, merus 2.2, carpus and propodus 1.6; merus 2.5 times, dactylus twice as long as wide; exopodite reaching middle of meropodite (Fig. 133, *E*).

Pereiopods rather short, proportions in length to dactylus are as follows:—

	Ischium	Merus	Carpus	Propodus
First pereiopod	1.0	1.3	1.0	0.5
Second „	1.0	1.9	2.0	0.5
Third „	1.1	2.5	3.0	0.6
Fourth „	1.3	2.1	1.8	1.1
Fifth „	1.4	2.3	2.0	1.2

Thelycum made up of an anterior and a posterior median elevations and a pair of lateral ones. Anterior median elevation about 5 times as long as wide, slightly narrowed at middle, ranging from middle of the last thoracic sternite to anterior base of fourth pereiopods; posterior one acute at apex, set close to posterior edge of the last thoracic sternite. Lateral ones arc-shaped, greatly separated from each other, thrice as long as wide, somewhat narrowed posteriorly, sharply pointed at antero-median angle (Fig. 47, *E*).

Branchial arrangement (Table 6, *I*) closely related to that of *Trachypenaeus curvirostris* (STIMPSON). But only difference is that anterior vestigial (simply filamentous) arthrobranchia of seventh thoracic somit present as is the case with *Trachypenaeopsis mobilispinis* (RATHBUN).

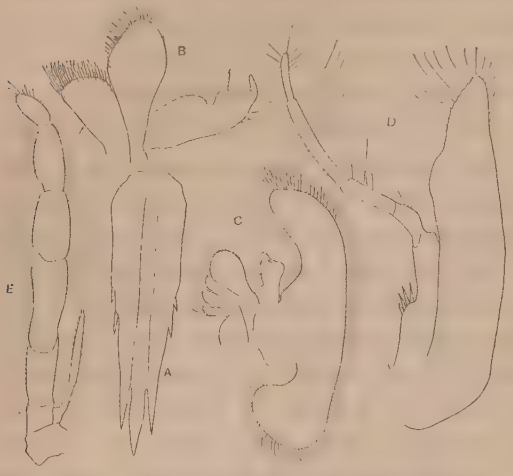

Fig. 133. *Trachypenaeopsis richtersii* (MIERS), *A*, telson in upper aspect, ×6; *B*, maxillula, ×16; *C*, maxilla, ×8.4; *D*, first maxilliped, ×16; *E*, third maxilliped, ×6.

Cardiac plate carries about a dozen of equidistan spinules alined longitudinall (Fig. 81, *J*). Pterocardia ossicle simply bar-shaped Zygocardiac is of Type–*R* upper row has 4 rathe rudimentary teeth, the othe about 10 sharply pointe ones (Fig. 81, *J*). Uro cardiac rounded at anterio end, bearing a large proces with bluntly pointed ape directed sidewise on eac lateral border near anterio end (Fig. 74, *R*). Prepylori tapers into a pointed media tooth, furnished along eac postero-lateral edge with conical teeth, each of which is much smaller than the median one (Fi 74, *X*).

The description and illustrations given above are based on a femal 42.5 mm long (11.4 mm in carapace-length). Further, 2 females, 42.5 m and 43.2 mm long respectively, were also examined. All of them we obtained from Miya, Aichi Pref., by Mr. G. ABE.

Distribution: Cerf Island, Western Indian Ocean (MIERS); Hawa ian Islands (RATHBUN); Banda-anchorage (DE MAN).

Note: In regard to the rostrum, it should be noticed that it inclination seems to be variable within a species. It is found slightl ascending in two specimens as in those of MIERS' RATHBUN and D MAN, but almost horizontal in a specimen which is represented in Fig 132. The lower margin is considerably convex, closely resembling D MAN's Fig. 19c, but not straight as in MIER's Fig. A. The tip a pears less acute as in RATHBUN's and DE MAN's specimens than in Fi A given by MIERS. The teeth lying on the upper border are 5 in specimen, 6 in two ones in number excluding the epigastric one.

The ischial spine of the first chelipeds is present in my specimen whilst the spine in question is absent in Hawaiian specimens accordin to RATHBUN's description. But it appears to have been overlooked b him, since it is so minute as not recognizable unless with aid of a len of high power.

The present three specimens differ from all the descriptions and figures given by MIERS, RATHBUN and DE MAN in having longer rostrum, reaching a little behind distal end of the eye instead of extending about half-way to the end of the eyes. From MIERS's account and illustration, they also differ by possession of an acute spinule at posterior extremity of the mid-dorsal carina of the sixth abdominal somite (this item cannot be ascertained in DE MAN's specimen, since its abdomen is mutilated). From DE MAN's description they are discrepant in the points as tabulated below.

Items	present specimens	DE MAN's specimens
1. Antennular flagella	upper ramus a little shorter than the other	equal in length
2. Fifth leg	merus ca. 7 times, propodus 5 times, dactylus 4.5 times, as long as wide respectively	merus 4 times, propodus 3 times, dactylus 4 times, as long as wide respectively

And yet agreement with those accounts given above in other all important characters is so obvious as to warrant one to refer the specimens dealt with to the present species.

The present species shows an especial relation to *Metapenaeus* in possession of the following characteristics: thelycum is of Type–N_7, and zygocardiac Type–R_6.

Genus *Atypopenaeus* ALCOCK

Atypopeneus, ALCOCK, 1905, p. 524; 1906, p. 45.
Atypopenaeus, DE MAN, 1911, p. 83.

Only two species, *Atypopenaeus compressipes* (HENDERSON) and *A. dearmatus* DE MAN [1911, pp. 84–87, Pl. 8, fig. 27 (1913)] are hitherto known from Indo-Pacific waters. They have branchiae as follows: a pleurobranchia present on the thoracic segments from the second to the sixth; a rudimentary arthrobranchia on the first in *A. compressipes* alone, a well developed one on the seventh, and two ones on the segments from the second to the sixth; a podobranchia on the second; and a mastigobranchia on the first, second and the fourth to the sixth (Table 6, *F*).

The vestigial arthrobranchia of the first thoracic segment is absent in *A. dearmatus* according to DE MAN (*op. cit.* p. 87). But it appears to the writer that the branchia was perhaps overlooked by him. It is particular to the abovementioned two species belonging to the present genus to have a pleurobranchia on the second thoracic somite among all the species of the two subfamilies, Penaeinae and Solenocerinae which have come under the author's examination.

A. compressipes and *A. dearmatus* may be distinguished as give
below.

Key to the species of *Atypopenaeus*.

A₁. Petasma not suddenly constricted in distal one quarter, disto-lateral cornua directe
anteriorly; thelycum with lateral plates reaching about middle of the median plate.
.........*A. compressipe*

A₂. Petasma suddenly constricted in distal one quarter, disto-lateral cornua directe
sidewise; thelycum with lateral plates extending to about two-thirds of the media
plates ....*A. dearmatu*

Atypopenaeus compressipes (HENDERSON)

(Figs. 1, *T*; 7, *W*; 32, *E* and *F*; 47, *I*; 64, *G*; 71, *N*; 76, *B* and *G*; 79, *B*; 135,
E)

Atypopeneus compressipes, ALCOCK, 1906, pp. 45–46, pl. 9, figs. 29 and 29*a*.
Atypopenaeus compressipes, DE MAN, 1911, pp. 83–84.
Penaeus compressipes, HENDERSON, 1893, pp. 450–451, pl. 40, figs. 21 and 22.
Parapenaeopsis brevirostris, KUBO, 1936, pp. 55–58, pl. 16, figs. *A–D*.

Post-ocular groove well-marked. Cervical one clearly cut, straig
reaching a third toward two-thirds of mid-dorsal line of carapa
Orbito-antennal not recognizable. Hepatic and branchiocardiac app
slightly indent, the former horizontally straight. Supra-orbital an
well-defined, but not spiniform. Pterygostomian angle rounded.
small, one-seventh the length of carapace in longer diameter of corne
a compressed triangular process present on upper distal edge of ba
segment. Prosartema reaches somewhat behind anterior end of e
Stylocerite extending as far as half-way of first antennular segme
Antennular stalk slender; basal segment has an acute spine directed f
ward at antero-lateral angle; the intermediate somewhat shorter th
basal one, about 2.3 times as long as the last segment. Basicerite wi
out a spine on antero-lateral rim. Scaphocerite attains tip of antennu
peduncle, slightly narrowed forwards, 3.2 times as long as wide, with
acuminate disto-lateral spine which is barely exceeded by apex of lame
Carpocerite extending as far as eye, thrice as long as wide.

Mandible: molar process circular and flat on masticatory surf
Incisor one with sharp and entire cutting border. Palp reaching bas
carpocerite; basal article deltoid in outline, 1.2 times as long as wi
the distal lunate with convex margin sidewise, twice the width,
twice the length of the basal (Fig. 7, *W*). Maxillulary palp is of Ty
F_2; basal segment narrowed distally by a third, a little more than tw
as long as wide measured near base, bearing a large swelling with roun
apex in proximal half, a spinous seta at two-thirds of anterior bor
and furnished with a similar but a little smaller swelling than that

anterior border near base of the posterior; distal segment very minute, with rounded apex, as long as wide, one-eleventh the length of basal one (Fig. 135, *E*). Maxilla is of Type–G_1; endopodite with a pointed projection at distal inner angle. First maxilliped belongs to Type–H_{2a}; inner distal endite thrice the width; endopodite 4-jointed, ratios in length to the last segment: first 1, second 0.2, third 0.5, fourth 1.1; basal joint has a large seta near mid-way of anterior edge; the penult slightly narrowed distally, 7 times as long as wide measured near base; exopodite subrhombic in outline with distal margin running antero-laterally, extends to far end of fourth joint of palp; 7 times the width, tapers into a point in distal one quarter. Second one as usual in shape, meropodite two and half times the width, 1.7 times the length of dactylus. Third simply pediform, ratios in length to dactylus: ischium 1.2, merus, carpus, and propodus 1.5 respectively.

Third pereiopod hardly reaches apex of scaphocerite, proportions in length to movable finger: ischium 0.6, merus and carpus 2.6, palm 0.66; merus about 5 times as long as wide. The last leg extending beyond tip of antennal scale by dactylus; ischium 0.6, merus 1.2, carpus 0.8, propodus 1.3 in relative lengths to dactylus.

Appendix masculina is of Type–O_7, closely resembles that of *Metapenaeopsis barbatus* (De Haan) and its congeners, but its terminal portion is more strongly expanded than that of the said forms (Fig. 64, *G*).

Petasma well corresponding to Alcock's Fig. 29 a. With regard to the apparatus of a young form, a description was given already in the general part of this paper (Fig. 32, *E* and *F*).

Thelycum belongs to Type–N_7; median plate with rounded anterior and posterior ends, somewhat narrowed toward middle, larger than lateral one (Fig. 47, *I*).

Cardiac plate bears about 27 spinules (Fig. 79, *B*). Pterocardiac ossicle bar-shaped, more or less narrowed distally, slightly curves backward in outer half, with a slender, bluntly pointed projection running parallel to antero-lateral edge of urocardiac ossicle on median border. Prezygo-cardiac sigmoid, pointed at both inner and outer ends (Fig. 71, *N*). Zygocardiac is of Type–R_3 (Fig. 79, *B*). Urocardiac abruptly narrowed into a rounded apex at anterior end, and has a pair of large bluntly pointed lateral processes near anterior end (Fig. 76, *B*). Prepyloric ends in a large median tooth with rounded apex, armed on each postero-lateral edge with 5–7 teeth which are much smaller than the median one in size (Fig. 76, *B* and *G*).

Branchial formula is given in Table 6, *F*. All mastigobranchiae one-lobed.

Examined 12 males, 28–39 mm long (8–12.7 mm in carapace-length) and 31 females, 35.2–49.0 mm long (10.8–14.9 mm in carapace-length).

Locality: Ushimado, Tomo, and Mitaziri, Inland Sea of Japan.

Distribution: Martaban (HENDERSON); Madrus (12 fathoms) (ALCOCK); Bay of Bima (DE MAN); Inland Sea of Japan (KUBO).

Note: The abdomen is dorsally carinated from the second to sixth somites, but the carina of the second somite, which was probably overlooked by HENDERSON (*op. cit.* p. 451) and ALCOCK (*op. cit.* p. 46), is very weakly defined as described by DE MAN (*op. cit.* p. 84). Moreover, the carina, especially that of the second and third somites, becomes better marked with advance of growth. The description formerly given by the writer (KUBO, 1936, p. 57) concerning to this item is erroneous.

The chelae of the second and third pereiopods of the present specimens agree with HENDERSON's illustration. But they differ from ALCOCK's Fig. 29, in which the fingers of these pereiopods are indicated considerably shorter than the palms of the limbs.

All our specimens are well in accordance with the descriptions and figures given by HENDERSON, ALCOCK and DE MAN, except such minute differences given above. Therefore the specimens on hand are identified with the present species. *Penaeus stenodactylus* STIMPSON, (1860, p. 431) from Hongkong is intimately related to the present species. It is, however, discrepant from the latter by having the following characteristics: "Carapax carinatus (quarta parte posteriore excepta) laevis nisi dorso subtilies, appendics antennarum superantes."

The present animal has been regarded rare by previous investigators. But it is found rather commonly, although not abundant, among other prawns: *Metapenaeopsis barbatus* (DE HAAN), *Metapenaeopsis acclivis* (RATHBUN), and *Trachypenaeus curvirostris* (STIMPSON), in summer in such localities given above.

Genus *Parapenaeopsis* WOOD-MASON, MS (emend)

Parapeneopsis, ALCOCK, 1901, p. 14, and 1906, pp. 34-35;
Parapenaeopsis, BALSS, 1914, p. 14; and 1925, p. 229; DE MAN, 1911, pp. 9, 92-93; BURKENROAD, 1934 *b*, pp. 58-59.

Rostrum well developed, with many teeth above, but none below. Carapace with longitudinal and transverse sutures, the former running backwards from orbital margin but never reaching the posterior edge, the latter acrossing branchio-stegite. Postrostral carina present or absent. Ante-gastric, orbito-antennal, antennal and branchio-cardiac grooves rather marked or absent. Cervical and hepatic ones well-developed. Supra-orbital angle well-defined, sometimes dentiform. Pterygostomian angle not spiniform. Epigastric spine present or absent. Antennal and hepatic ones always present. Abdomen dorsally carinated. Telson has a dorso-median sulcus, armed with minute spinules or unarmed. Antenular flagella moderately or considerably long (*i. e.*, about twice as long as carapace). Maxillulary palp mostly two-segmented but sometimes unsegmented. Fifth pereiopod usually normal but rarely filamentous. Endopodite of second pleopod of male sometimes greatly transformed. Appendix masculina 2 or 3-jointed with horse-hoof-shaped or rather slender cup-shaped apical segment. Petasma symmetrical with a pair of long or short disto-lateral horns. Thelycum with an anterior broad median plate, Pterocardiac ossicle is of Type–Q_1.

Pleurobranchiae absent in last two thoracic somites. Mastigobranchiae of first and second pereiopods present or absent (Table 6, *K* and *M*).

The accounts of the following 8 species of the present genus are embodied in the present paper: *Parapenaeopsis tenellus* (BATE) *P. cornutus* (KISHINOUYE), *P. maxillipedo* ALCOCK, *P. hungerfordi*, ALCOCK, *P. gracillima*, NOBILI, *P. hardwickii* (MIERS), *P. cultrirostris*, ALCOCK, and *P. sculptilis* (HELLER) On the characters significant for the classification of these species, some comments should be made as given below.

Peculiar to *P. tenellus* and *P. gracillima* is the absence of the epigastric spine. The total abdomen except telson is dorsally earinated in *P. sculptilis*, but the anterior two or three abdominal somites are dorsally rounded in the others. The longer antennular flagellum ranges from about half length to nearly full length of the carapace in all but *P. gracillima*, in which it is a little more than twice as long as carapace. That fifth pereiopods are long and filamentous is characteristic to *P. gracillima* only, common to all others being longish and rather stout ones. The endopodites of the second pleopods undergo a striking modification in the two species: *P. cornutus* and *P. hungerfordi*. The petasma of *P. tenellus*, *P. cornutus*, *P. maxillipedo* (according to ALCOCK, 1906) and *P. hungerfordi* is characterized by possession of a pair of conspicuous disto-lateral or distal projections, whilst that of the rest except *P. gracillima*, of which no male is represented in the present material, is fnrnished with short ones, besides a pair of large auriculate basal lateral expansions which are probably peculiar to *sculptilis*-group. The thelycum is found, throughout all the forms dealt with, furnished with a broad tumid anterior median plate, and that of *P. cornutus*, *P. maxillipedo* and *P. sculptilis* even with a tuft of long hairs somewhere else. The appendix masculina of *P. tenellus*, *P. cornutus* and *P. hungerfordi* consists of three segments, having a thickend horse-hoof-shaped apical one, on the other hand, that of *P. hardwickii* and *P. sculptilis* is two segmented with rather slender cup-shaped apical joint. However, it is not known in *P. maxillipedo*, *P. sculptilis*, and *P. gracillima*. The cardiac plate is provided with more than 40 equidistantly set and longitudinally alined spinules in *P. cornutus* and *P. maxillipedo*, but with 15–19 ones in the rest. The mastigobranchiae are absent on the first two pairs of pereiopods of *P. tenellus* and *P. hungerfordi*, but absent in the corresponding pairs of all others.

Basing on presence or absence of the mastigobranchiae on the first and second pereiopods, the forms dealt with are grouped into two, viz., Group–A_1 and–A_2. The former is represented by *P. tenellus* and *P. hungerfordi*, the latter by *P. cornutus*, *P. maxillipedo*, *P. hardwickii*, *P. cultirostris*, *P. sculptilis*, and *P. gracillima*. Among the species belonging to Group–A_2, *P. gracillima* is far remote from others in having no epigastric spine, strikingly longer antennular flagella, and filliform fifth pereiopods. The remaining species of the group–A_2 are again divisible into two subdivisions, one of which comprises *P. cornutus* and *P. maxillipedo*, and the other includes *P. sculptilis* and its allied forms. *P. cornutus* and *P. maxillipedo* are characterized by having such petasma as is furnished with outstandingly elongated disto-lateral projections and also cardiac plate with more than 40 spinules on inner surface. On the other hand, *P. sculptilis* and its congeners are separated from the former subdivision by the possession of petasma with short disto-lateral horns and cardiac plate with 15–19 spinules. Considering the facts given above, the annexed key is prepared.

Key to the species of Genus *Parapenaeopsis*.

A_1 Mastigobranchiae absent on first and second pereiopods

  B_1 Rostrum reaching about middle of first segment of antennular peduncle, armed above with 6-8 teeth along its entire length. Postrostral carina and epigastric spine absent. Abdomen dorsally carinated posterior to third segment. Endopodites of second pleopods normal in shape. Appendix masculina three-segmented with thickened horse-hoof-shaped apical segment. Petasma with a pair of pointed slender disto-lateral projection. Thelycum with broad, subrhombic anterior median plate ....*P. tenellus.*

  B_2 Rostrum somewhat surpassing tip of antennular peduncle, armed above with 6 or 7 teeth (exclusive of epigastric one), unarmed in distal third. Postrostral carina almost reaching to posterior border of carapace. An epigastric spine present. Abdomen dorsally carinated backward to second segment. Endopodites of second pleopods greatly modified in shape. Appendix masculina two-segmented with rather slender cup-shaped distal joint. Petasma has a pair of large distal projections with truncate apex directed anteriorly. Thelycum with a large subrectangular median plate ....*P. hungerfordi.*

A_2 Mastigobranchiae present on first and second pereiopods

  C_1 Epigastric spine present. Antennular flagella shorter than carapace. Fifth pereiopods as usual in shape. A basial spine present on each of first and second chelipeds

    D_1 Petasma has a pair of long slender projections at distolateral corners of lateral lobes. Thelycum with a pair of rather broad lateral lobes behind anterior broad median lobe, and a tuft of long hairs behind middle of posterior edge of the last thoracic sternite. Cardiac plate has spinules more than 40 in number

E1 Third pereiopods of female without a basal spine. Cardiac plate with 42–49 spinules. ....*P. cornutus.*

E2 Third pereiopods of female with a basal spine. Cardiac plate with 56–59 spinules ....*P. maxillipedo.*

D2 Petasma has a pair of short disto-lateral horns directed sidewise or somewhat antero-laterally on lateral lobe. Thelycum possesses a rather broad transverse ridge along posterior margin of the last thoracic sternite besides anterior broad semicircular or subtrapezoidal median plate, without a tuft of long hairs behind middle of posterior edge of the hindmost thoracic sternite. Cardiac plate has 15–19 spinules

F1 Epigastric spine stands at a fourth of carapace. First and second pleonic somites dorsally rounded; each of fourth and fifth ones without spinule at posterior end of dorso-median carina. Telson carries 3-5 pairs of minute dorso-lateral spinules. Antennular (longer) flagellum 0.7–0.9 times the length of carapace. Apical projection of median lobe of petasma not so large as compared with disto-lateral projection of lateral lobe

G1 Rostrum sigmoid, unarmed in distal one-third of the length, reaching well beyond tip of antennular peduncle. Petasma has lateral borders straight between basal auriculate projections and disto-lateral horns ....*P. hardwickii.*

G2 Rostrum assuming the form of a dagger, somewhat decurved, armed along its entire length, extending to about middle of intermediate joint of antennular peduncle. Petasma has lateral borders somewhat swollen between proximal auriculate projections and disto-lateral horns ....*P. cultrirostris.*

F2 Epigastric spine set at a fifth of carapace. First and second pleonic somites with a low shallowly canaliculated dorso-median carina; each of fourth and fifth ones has a spinule at posterior end of dorso-median carina. Telson devoid of spinules. Antennular (longer) flagellum about 0.4 times as long as carapace. Apical projection of median lobe of petasma wing-like, much larger than disto-lateral projection of lateral lobe. Thelycum provided with a tuft of long hairs at middle of posterior plate ....*P. sculptilis.*

C2 Epigastric spine absent. Antennular flagellum (inner) 2.2 times as long as carapace. First and second pereiopods without basial spine. Fifth pereiopods filamentous, surpassing scaphocerite by distal two segments. Thelycum consists of broad anterior and posterior plates with a rather deep median depression ....*P. gracillima.*

Parapenaeopsis tenellus (BATE)

(Figs. 1, *N*; 7, *G'*; 22, *J*; 32, *A* and *B*; 47, *M*; 63, *E* and *F*; 75, *E* and *K*; 78, *N*; 134, *A*, *B*, *E*, and *F*; 135, *D* and *H*)

Parapenaeopsis tenella, DE MAN, 1911, pp. 9, and 92; BALSS, 1914, p. 11; KUBO, 1936, pp. 58–60; OSADA, TANIZAKI and NAKAZAWA, 1936, p. 8, Pl. 4, lower (right); YOSHIDA, 1941, pp. 15-16, Pl. 3, figs. 2-2', and text-fig. 8.

Penaeus (Parapenaeopsis) tenellus, DE MAN, 1907, pp. 435-436, and 454.

Penaeus tenellus, BATE, 1888, pp. 270 271; KISHINOUYE, 1900, p. 22, Pl. 6, fig. 3, and Pl. 7, fig. 8.

Penaeus curcifer, ORTMANN, 1890, p. 451, Tab. 36., fig. 5a, b.

Post-ocular groove wanting. Orbito-antennal one ill-defined. Cervical and branchio-cardiac ones not marked. Hepatic carina well-developed, short and decurved. Supra-orbital angle well-defined, but not spiniform. Sixth pleonic somite one-fifth longer than the greatest width; a little less than half the length of carapace, armed with a spinule a trifle in front of postero-lateral angle besides that lying at posterior extremity of mid-dorsal carina. Telson well exceeded by tip of inner uropods. Eye measures a little less than a quarter (not about one-fifth, Kubo, 1936, p. 58) the length of carapace in longer diameter of cornea; a minute plate present at upper disto-median angle of peduncular segment as in that of *Atypop. compressips.* Antennular peduncle two-thirds the length of carapace; intermediate article 2.2 times as long as the last. Antennular flagella about half as long as carapace. Scaphocerite reaches tip of antennular peduncle, distally narrowed by half, 2.5 times as long as width measured at base, with a sharp disto-lateral spine which extends as far as apex of lamella. Carpocerite stretches below middle of cornea, two and half times as long as wide.

Mandible: molar process almost flat on masticatory surface, with somewhat produced sharp inner masticatory edge. Incisor one with a notch near anterior end of cutting rim. Palp similar to that of *Atypop. compressipes;* basal joint a little shorter than the greatest width; the distal twice as long as wide, 2.7 times the length of basal one (Fig. 7, *G'*). Maxillulary palp two-segmented, basal joint subrectangular in outline, 2.3 times as long as wide, carries a protuberance with two large setae at disto-lateral angle, and has a conspicuous swelling with rounded apex close to base of posterior edge; distal one small, tapering into a rounded apex, a seventh the length of basal one (Fig. 135, *D*). First maxilliped resembles that of *Atypop. compressipes* in general feature; inner distal lacinia ogival in outline, 2.9 times the width; palp 5-segmented, ratios in length to the last joint: first 1, second 0.3, third 0.5, fourth 1.1; penult article 6 times as long as wide; exopodite six and half times the width; gradually narrowed into a point in distal third. Second one normal in shape; meropodite 2.5 times as long as wide, 1.5 times the length of dactylus. Third one considerably depressed; ratios in length to dactylus: ischium and propodus 1.3, merus and carpus 1.2; merus half as wide as long, thrice the width of dactylus.

First leg reaches beyond pterygostomian angle of carapace by half of chela. Second extends as far as distal end of basicerite. Third reaching far end of carpocerite; ratios in length to movable finger: ischium 1.5, merus 2.5, carpus 3.5, propodus 0.5. Fourth stretching as far as third one. Fifth a little surpassing distal end of first antennular segment; relative lengths to dactylus: ischium 1.5, merus 3.5, carpus 3.8, propodus 1.8. A prominent basial spine present on first and second pereiopods. Exopodite of third maxilliped attains middle of the carpus; that of first four pereiopods reaching half-way of ischium, and that of the last one very minute, but not wanting (De Man, 1907, p. 454).

A pleurobranchia present on each thoracic sternite from third to sixth. An arthrobranchia on first and seventh thoracic somites, but that of first one vestigial, and a pair on each of somites from second to sixth. A podobranchia on second somite only. A mastigobranchia on first two maxillipeds.

Appendix masculina is of Type-O_8; apical article horse-hoof-shaped in adult form (Fig. 63, *E*), but very characteristic with a tongue-like appendage at center of circular depression of apical surface in a young form, 21 mm long (6 mm in carapace-length (Fig. 63, *F*).

Petasma represents such features as shown in Kishinouye's Fig. 32, *A* and *B*. Each petasmal endopodite of the young specimen given above does not yet appear to be united together with each other, measuring about 1.5 mm long, 5.5 times as long as wide; disto-lateral horn not yet closed, a third the length of the endopodite (Fig. 134, *A* and *B*).

Thelycum composed of anterior and posterior plates. Anterior plate broad, subrhombic with rounded or slightly emarginate anterior border, as long as wide, somewhat concave on ventral surface. Posterior one nearly V-shaped with pointed antero-lateral ends which attain middle of the last thoracic sternite, and has a narrow submarginal groove running nearly parallel to each anterior border (Fig. 47, *M*).

Cardiac plate with 24–28 equidistant spinules alined in a longitudinal series (Fig. 78, *N*). Cardiac ossicle lunate, twice as wide as long (Fig. 135, *Ha*). Pterocardiac bar-shaped, gradually tapering into a point in both inner and outer quarters, about 7 times as long as wide measured at middle, five times the length of cardiac ossicle (Fig. 135, *Hb*). Prezygocardiac crescentic, about a quarter the

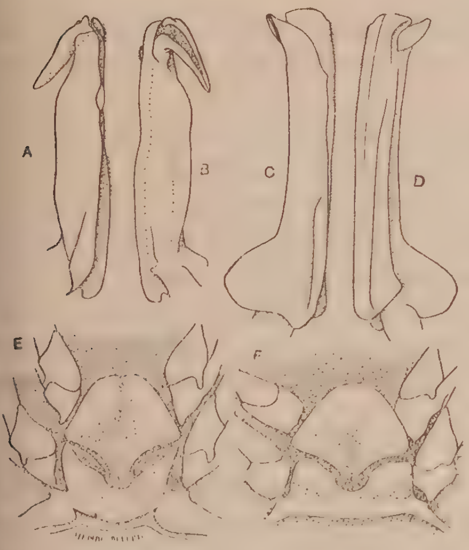

Fig. 134. Ventral (*A* and *C*) and dorsal (*B* and *D*) aspects of young form of petasma, and thelycum (*E* and *F*). *A* and *B*, *Parapenaeopsis tenellus*, 21 mm in body-length (6 mm in carapace-length), ×25; *C* and *D*, *Parapenaeopsis hardwickii*, 43 (13), ×15; *E*, *P. tenellus*, 49 (13), ×7.5; *F*, *P. tenellus*, 22 (6.5), ×15.

length of pterocardiac (Fig. 135, *Hc*). Zygocardiac with many sparsely set acute irregular teeth (Fig. 78, *N*). Urocardiac rounded at anterior end, triangularly expanded on each side near anterior edge (Fig. 75, *E*, and Fig. 135, *Hd*). Prepyloric subpentagonal in upper aspect, narrowed into a median tooth in posterior half, furnished on each post-lateral margin with about 13 accessory teeth which get gradually larger posteriorly; the median tooth twice as large as the rearmost accessory one (Fig. 75, *E* and *K*).

The description given above is taken from a female, 61 mm long (18.6 mm in carapace-length), secured from Miya, Aichi Pref. In addition to this, 8 males, 33.5–41.5 mm long (8.9–11.2 mm in carapace-length), and 50 females, 10.9–17.5 mm in carapace-length, were also examined.

Locality: Miya; Tomo, Hiroshima Pref., Sashiki, Kumamoto Pref.

Distribution: Bay of Kobe; Japan (Bate); lower half of Japan (Kishinouye); Inland Sea of Japan (De Man); Sashiki (Osada, Tanizaki, and Nakazawa); Southern and Southern half of Western coast of Tyôsen. (Yoshida).

Note: The body is a little scabrous, with rather sparsely set short setae as described by De Man, but not merely smooth and naked as mentioned by Bate and Kishinouye.

The telson of the present specimens agrees with De Man's description; but stands at variance with Bate's one which is probably erroneous in this respect.

The thelycum largely agrees with Kishinouye's Fig. 8. But the anterior plate is represented relatively narrower in his figure, namely, it is much longer than wide instaed of being as long as wide in adult form or even wider than long in young form at least smaller than 49 mm in length without rostrum so far as the present materials are concerned. The narrow submarginal groove of each anterior border of the posterior plate, which has been overlooked by all the previous investigators, is not defined in juvenile specimens at least smaller than 22 mm in length (Fig. 134, *E* and *F*).

Young of the present animal are closely related to those of *Trachypenaeus curvirostris* (Stimpson), but easily discernible from the latter by having naked shell, thinner antennular flagella and pereiopods. They are also very similar to those of *Penaeus*, but characterized by such larger eyes.

Parapenaeopsis cornutus (Kishinouye)

(Figs. 7, *Z*; 10, *B*; 22, *I*; 32, *C* and *D*; 47, *N*; 63, *A* and *B*; 75, *F* and *L*; 78, *L*; 135, *C*; 136, *A* and *B*).

Parapeneopsis cornutus, Maki and Tsuchiya, 1923, pp. 43-44, Pl.4, fig. 1.
Parapenaeopsis cornata, De Man, 1911, p. 93.

Penaeus cornutus, KISHINOUYE, 1900, p. 23, with a text-fig., Pl. 7, fig. 9.
Penaeus sp. OSADA, TANIZAKI, and NAKAZAWA, 1936, pp.6-7, Pl. 2 (upper, left).
Not: *Parapenaeopsis cornutus*, PARISI, 1919, pp. 64-65, Pl. 5, figs. 1 and 12.

Rostrum armed above with 7 or 8 teeth (including epigastric one), the last one of which stands a little backward to a quarter of carapace, penult one slightly behind post-orbital margins, and the foremost at about two-thirds of the carapace. Postrostral carina well-marked, with a transverse groove (without in female) lying at nine-tenths of carapace in male; but less prominent, vanishing at three-fourths of carapace in female. Post-ocular, orbito-antennal, antennal, hepatic, and branchiocardiac (only in male) grooves rather defined. Cervical groove straight and directed toward two-thirds of the median line of carapace, but fades out at about one-third of this direction. Hepatic runs nearly parallel to the cervical behind hepatic spine, curves suddenly downward in the rest and meets with inferior end of antennal groove at a distance from pterygostomian angle. Supra-orbital angle somewhat dentiform. Hepatic spine situated below epigastric one, smaller than the antennal. Sixth pleonic somite 1–1.2 times as long as wide measured at middle, about half as long as carapace, furnished with three spinules, one of which is located at posterior end of dorso-median carina and the rest at each post-lateral angle. Telson 1.2 times the length of sixth abdominal somite, greatly exceeded by apex of inner uropods. Outer uropod more or less longer than the other, and has a spinule at disto-lateral angle.

Eye one-fourth the length of carapace in longer diameter of cornea. Prosartema extends as far as anterior margin of eye. Stylocerite reaching slightly behind middle of first antennular segment. Antennular peduncle a little surpassing tip of rostrum; intermediate article somewhat shorter than basal one, thrice the length of distal one. Antennular flagella subequal in length, about half the length of carapace, upper ramus much thinner than the other. Basicerite without spine on antero-outer edge. Scaphocerite three times as long as wide measured at base, narrowed distally by two-fifths, furnished with a disto-lateral spine which extends as far as apex of lamella. Carpocerite stretches as far as stylocerite, 1.5 times as long as wide.

Mandible: molar process with somewhat indent and subquadrate distal surface, in possession of a rather markedly produced and sharp inner masticatory edge ending in an acute tooth posteriorly. Incisor one with sharp cutting rim which has a notch at about middle and forms a pointed tooth at anterior end. Palp reaching to midway of carpocerite; basal segment typical in feature; the distal with pointed apex directed antero-laterally, proximally expanded with markedly convex outer margin, twice the width measured in the broadest region, three times the length of basal article (Fig. 7, *Z*). Maxillulary palp two segmented; basal one subrectangular, 2.2 times as long as wide, with a large expansion at middle of anterior border and near base of posterior one, and a spinous bristle at disto-median angle; distal segment minute, triangular in outline, attaches at disto-lateral angle of basal joint, 9 times the length of basal one (Fig. 135, *C*). First maxilliped is of Type-H_{2a}; inner distal lacinia thrice the width; endopodite 5-segmented; ratios in length to the last joint: first 1.1, second 0.3, third 0.5, fourth 1.4; first article with a conspicuous seta at middle of anterior margin; exopodite narrow, 8 times as long as wide, tapers into a bluntly pointed apex in distal third. Second maxilliped normal in shape, meropodite 2.4 times as long as wide, 1.7 times th length of dactylus. Third on reaching beyond carpocerit by dactylus, proportions i length to the last joint ischium 2.0, merus and pr podus 1.3, carpus 1.4; carpo podite the widest of all th joints, ca. 1.7 times as lon as wide.

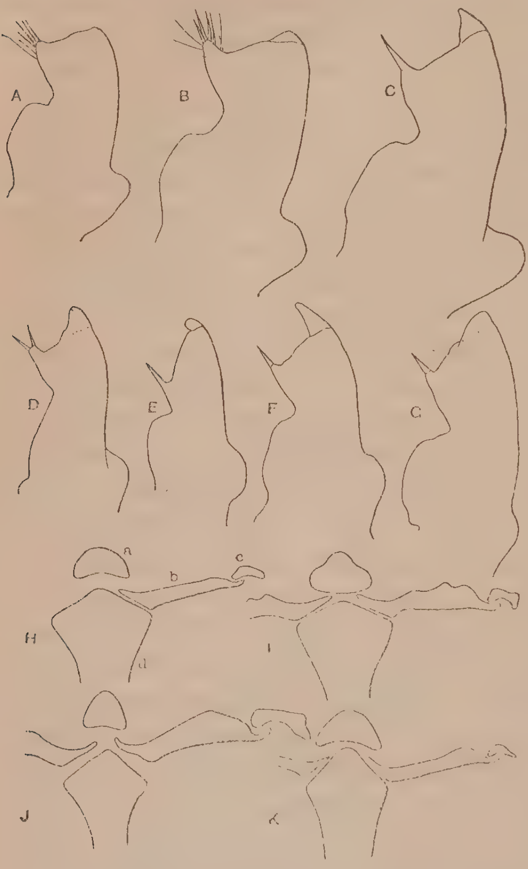

Fig. 135. Maxillulary palp (*A*–*G*) and cardiac (*a*), pterocardiac (*b*), prepyloric (*c*) and anterior half of urocardiac (*d*) ossicles (*H*–*K*). *A* and *J*, *Parapenaeopsis cultrirostris*; *B*, *Parapenaeopsis hardwickii*; *C*, *Parapenaeopsis cornutus*; *D* and *H*, *Parapenaeopsis tenellus*; *E*, *Atypopenaeus compressipes*; *F* and *K*, *Parapenaeopsis hungerfordi*; *G* and *I*, *Parapenaeopsis sculptiris*. *A*–*D* and *F*, ×20; *E*, ×25; *G* and *J*, ×10.5; *H* and *K*, ×15; *I*, ×7.5.

First pereiopod extends t proximal end of third segmen of antennal peduncle. Secon reaches far end of carpocerit Third surpassing distal end c carpocerite by entire chel ratios in length to movab finger: ischium 1.3, mer 2.3, carpus, 4, palm 0. meropodite about 3.9 times long as wide. Fourth attain half-way of carpocerite. Fift reaches beyond tip of carpocerite by half of dactylus, relative lengths t the last joint: ischium 1.5, merus 2.7, carpus 3.1, propodus 1.6.

Genital sternite of male has an ill-calcified somewhat pilose tongu like projection directed antero-ventrally near anterior edge.

Second pleopod of male very characteristic; endopodite assumes the outline of a boot, consists of many joints, furnished with a number of conical setae along distal margin (Fig. 63, *B*). Appendix masculina three-segmented; the last segment horse-hoof-shaped as in that of *P. tenellus*, with many short setae along distal inner edge (Fig. 63, *A*).

Petasma and thelycum well resemble KISHINOUYE'S Fig. 9, the thelycum associated with a tuft of long hairs behind middle of posterior margin of the last thoracic sternite, the tuft proximally yellow and distally blue in life (Fig. 32, *C* and *D*, and Fig. 47, *N*).

Cardiac plate with 41–46 longitudinally alined spinules (Fig. 78, *L*). Cardiac ossicle deltoid, with rounded corners, four-fifths wider than long. Pterocardiac bar-shaped, gradually narrowed sidewise into a bluntly pointed tip. Prezygocardiac more or less arc-shaped. Urocardiac bluntly pointed at anterior end (Fig. 75, *F*). Zygocardiac with many irregularly set spines, besides 3 large acute teeth lying on anterior edge, the dorsalmost of the three is followed by 3 accessory ones arranged longitudinally (Fig. 78, *L*). Prepyloric furnished on each post-lateral border with about 15 pointed teeth which get successively larger backward; the last of the series somewhat smaller than median one (Fig. 75, *F* and *L*).

Colour in life: Body faintly pinkish with many transverse blue bands resembling those of young form of *Penaeus japonicus*. Uropods proximally red, and distally greenish blue. Antennal flagella reddish and crossed by broad yellow bands.

The description and illustrations given above are based on a male and a female, 83 mm and 74.5 mm long (24 mm and 22 mm in carapace-length) respectively, obtained from Ariake-wan, Kyûsyû. Other 5 females, 49–72 mm long (15–21 mm in carapace-length), were also examined, 4 of which were collected from the same locality noted above, and the rest from Tainan, Formosa by the late Mr. OO-U-KIJO.

Distribution: Ariake-wan (KISHINOUYE, OSADA, TANIZAKI, and NAKAZAWA); Java (DE MAN); Takao and Tainan, Formosa (MAKI and TUCHIYA).

Note: The specimens dealt with well tally with the accounts given by KISHINOUYE and others except the points given below. The rostrum is slightly sigmoid, closely resembling that of *Penaeus japonicus:* a little decurves in basal two-thirds, and somewhat recurves upwards in the rest in both sexes (Fig. 136, *A* and *B*), but not as in KISHINOUYE'S Text-fig., in which it is represented simply upcurved in distal third.

It should be also noticed in this place that male of this species has a basal spine, which has been overlooked by previous investigators, on each of the third pereiopods besides that of the first and second ones as is the case with *Parapenaopsis maxillipedo* ALCOCK.

De Man's specimen, one female from Anchorage off Djangkar, Java, well quadrates with our specimens, especially in the following items: conditions of the rostrum and the postrostral carina, and having no basial spine on the third pereiopods of female, chiefly by which the present species may be defined from its nearest form, *Parapenaeopsis maxillipedo.*

Parisi's two female specimens from Tansui, Formosa, referred to the present species by him, greatly differ from our specimens in the telson and thelycum, according to his illustrations (without description), in which the former is represented as bearing a welldefined dorso-median carina, and the latter as having anterior median plate comparatively larger and circular in outline and without a tuft of long hairs behind middle of posterior edge of the last thoracic sternite. Therefore his specimens should not be identified with the present species.

Parapenaeopsis cultrirostris, Alcock.

(Fig. 7, *Y*; 22, *K*; 29, *C* and *D*; 63, *H* and *H'*; 75, *N* and *T*; 78, *M*; 135, *A*, and *J* 136; 140.)

Parapeneopsis sculptilis var. *cultrirostris*, Alcock, 1906, p. 39, Pl. 7, fig. 23.
Parapenaeopsis cultrirostris, Yu, 1935, p. 116.

Adrostral groove vanishing somewhat backward to epigastric tooth. Post-ocular rather, and orbito-antennal hardly marked. Cervical and hepatic well-defined, the former straight, extending to half-way of its direction toward two-thirds of dorso-median line of carapace, the latter running anteriorly a little behind pterygostomian angle, and posteriorly to the line vertical through posterior end of cervical groove. Epigastric tooth minute, set at one-fourth of carapace as in *Parapenaeopsis hardwickii*, remote from ultimate rostral tooth, 2.5 times the distance between penult and antepenult ones. Hepatic spine placed below epigastric spine. Abdominal segments from first to third dorsally rounded, but those from fourth to sixth sharply carinated, and the carina of sixth somite ends in an acute spinule. Sixth pleonic somite 1.5 times as long as wide, a little more than half the length of carapace, with three cicatrices on lateral surfaces and minute spiniform postero-inferior corners. Telson about 0.6 times as long as carapace, well exceeded by apex of inner uropods, armed with several pairs of dorso-lateral spinules posterior to three-fourths, which are only recognizable by a high-power lens.

Eye comparatively large, 0.27 times the length of carapace in longer diameter of cornea. Prosartema attains a little backward to anterior margin of eye. Stylocerite extending to middle of basal antennular segment. Antennular peduncle stretches beyond tip of rostrum by about half of intermediate segment and the last one taken together; the intermediate 2.8 times as long as the third. Upper antennular flagellum slightly longer than the other, 0.9 times the length of carapace. Basicerite bears a spinule on disto-lateral border. Antennal scale closely resembles that of *Parapenaeopsis hardwickii* in general aspect, hardly reaching tip of antennular peduncle. Carpocerite extends as far as eye, about 2.5 times the width. Antennal flagella twice the length of body.

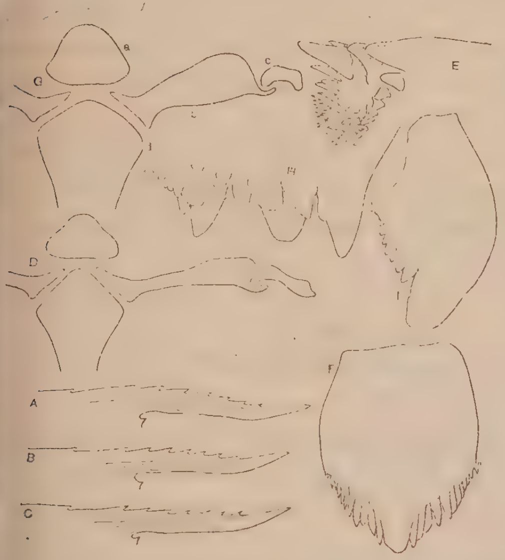

Fig. 136. *Parapenaeopsis cornutus* (*A* and *B*), *Parapenaeopsis maxillipedo* (*C*–*F*), and *Parapenaeopsis gracillima* (*G*–*I*). *A*, rostrum of a male, 83 mm long; *B*, rostrum of a female, 74.5 mm long; *C*, rostrum of a female, 75.9 mm long; *D* and *G*, cardiac (*a*), pterocardiac (*b*), prezygocardiac (*c*) and anterior half of urocardiac (*d*) ossicles; *E* and *H*, teeth of zygocardiac ossicle; *F*, prepyloric ossicle, dorsal aspect; *I*, prepyloric ossicle, lateral view. *A*–*C*, ×1.6; *D* and *G*, ×16; *E*, *F*, *H* and *I*, ×28.

Mandible: molar process a little concave and subrectangular on masticatory surface, somewhat pointed dentiform at postero-median angle. Incisor process with sharp and somewhat wavy cutting edge. Palp closely resembles that of *Parapenaeopsis sculptilis*, reaching base of carpocerite; second joint four-fifths longer than wide, 2.4 times the length of the first (Fig. 7, *Y*). Maxillulary palp very similar to that of *Parapenaeopsis hardwickii*, the disto-median protuberance of basal segment less developed, and the protuberance of second segment absent (Fig. 135, *A*). First maxilliped: inner distal endite rather narrow with rounded apex, 2.6 times as long as wide; palp five-jointed, proportion in length against the last joint, first 1, second 0.25, third 0.4, fourth 1.25; exopodite narrow, 9 times as long as wide, tapering into a bluntly pointed tip in distal about half. Second as usual in shape; meropodite two and half times the width, 1.7 times the length of dactylus. Third reaches to, or beyond, carpocerite, remerkably thicker than any pereiopods, ischium 2.5, merus 1.9, carpus 1.6, propodus 1.7 in relative length to the last joint.

First pereiopod attains distal edge of basicerite, movable finger twice the length of palm. Second surmounts basicerite by half of chela. Third extending as far as carpocerite, proportions in length to movable finger: ischium 1.1, merus 2.1, carpus 3, palm 0.9. Fourth reaches a little (ca. half of dactylus) beyond basicerite, bearing a notched appearance at base of posterior edge of meropodite as the edge suddenly expands near base and gradually narrows toward tne middle. Fifth surpassing carpocerite by dactylus, relative length to dactylus: ischium 1, merus 3.5, carpus 3.5, propodus 1.7.

Appendix masculina almost equals to that of *Parapenaeopsis hardwickii* (Fig. 63, *H*).

Petasma also very much related to that of the species in question, but lateral borders between basal auriculate appendages and distolateral horns appear considerably swollen, and apical margin of median lobe irregularly wavy in outer half (Fig. 29, *C* and *D*).

Stomodaeal ossicles very near to those of *Parapenaeopsis hardwickii* and *Parapenaeopsis sculptilis*, but spinules of cardiac plate and teeth set along each postero-lateral edge of prepyloric ossicle are about 15 and 11 in number respectively (Fig. 75, *N* and *T*, and 78, *M*).

Five males, 52.0–64.5 mm long, (14.2–18.0 mm in carapace-length), secured off South coast of Borneo, were examined.

Distribution: Orissa, Ganjam, Sunderbunds, Hooghly R. (ALCOCK); Amoy, Shin-chia-kan, Shantung Province (YU).

Note: The specimens under the examination well correspond with accounts of ALCOCK and YU, but only exception is that the rostrum has the straight lower border in YU's material instead of decurved one (Fig 140).

On comparing this species with its nearest ally, *Parapenaeopsis hardwickii*, it is easily distinguished from the latter basing on the diagnostic shape of the rostrum and the petasma, much smaller relative length (referred to carapace) of the rostrum (Fig., 139, *A*), and so forth as given in the key to the species of the present genus.

***Parapenaeopsis maxillipedo*, ALCOCK**

(Fig. 136, *C–F*)

Parapeneopsis maxillipedo, ALCOCK, 1906, pp. 40–41, Pl. 8, figs. 24 and 24, a–b.

Stomodaeal ossicles largely resemble those of *Parapenaeopsis cornutus* (Fig. 136, *D–F*), but with some differences as follows. Cardiac plate has 56–59 spinules. Cardiac ossicle with both lateral margins somewhat indent at middle. Pterocardiac anteriorly expanded in onter half. Prepyloric bearing 12–13 teeth along each postero-lateral edge besides a bluntly pointed median tooth which is about thrice as large as submedian ones.

Distribution: Madras, Bombay (ALCOCK).

Note: The writer has examined a female, 75.9 mm long (23.6 mm in carapace-length), obtained off South coast of Borneo, by Asist., Prof., S. SAITO. This single specimen well coincides with ALCOCK's description and illustrations of the present species. Hence it is referred to the form.

The present species so intimately resemble *Parapenaeopsis cornutus*, KISHINOUYE, as the former is only defined from the latter in the following respects.

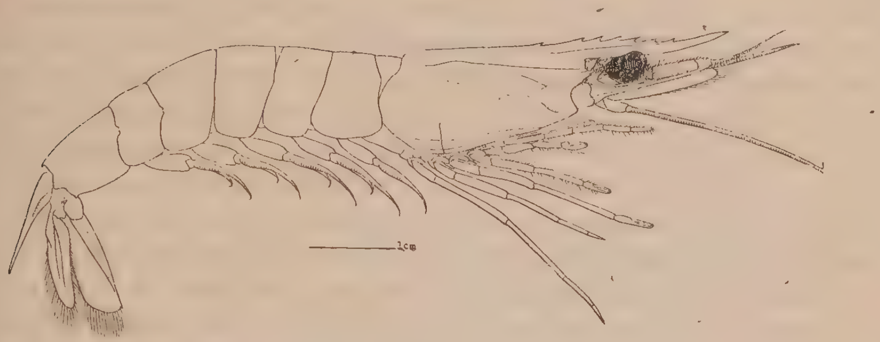

Fig. 137. *Parapenaeopsis cultrirostris* ALCOCK, male, 62 mm long.

	Items	*P. maxillipedo*	*P. cornutus*
(1)	Rostrum	horizontally straight in proximal two-thirds and somewhat recurves upward in the rest	slightly decurved in proximal two-thirds and somewhat uptilted in the rest
(2)	Post-rostral carina in female	extending to posterior margin of carapace	reaching to three-fourths of carapace
(3)	Antennular peduncle	strongly pubescent	less pubescent
(4)	Third leg of female	with a basial spine	without a basial spine
(5)	Cardiac plate	with 56-59 spinules	with 46-49 spinules

Parapenaeopsis hungerfordi, ALCOCK

(Figs. 7, *A'*; 22, *H*; 32, *G* and *H*; 47, *O*; 63, *C* and *D*; 75, *P* and *V*; 78, *P*; 135, *F* and *K*; 138).

Parapeneopsis hungerfordi, ALCOCK, 1905, p. 530.
Parapenaeopsis hungerfordi, BURKENROAD, 1934 *b*, pp. 65, 67-70, figs. 18 20; BALSS, 1924, pp. 44-45; YU, 1935, p. 166.

Supra-orbital angle somewhat spiniform. Post-rostral carina almost reaches to posterior margin of carapace, gradually narrowed posteriorly from about two-fifths of carapace, with a shallow longitudinal sulcus on dorsal surface. Orbito-antennal, antennal, cervical and hepatic grooves rather defined. Cervical straight, directed toward four-fifths of mid-dorsal line of carapace, and covers one-third of the distance. Hepatic downcurved; continuous to lower end of antennal one. Branchio-cardiac hardly recognizable. Sixth pleonic somite a third longer than wide about half the length of carapace, and has a spinule near each postero-inferior angle. Telson more or less longer than sixth abdominal somite

Eye rather large, a quarter the length of carapace in longer diameter of cornea. Prosartema hardly reaching to anterior rim of eye Stylocerite attains a little behind middle of first antennular segment Antennular peduncle well exceeded by rostrum; basal segment has a stout disto-lateral spine; the second 2.6 times as long as ultimate one Antennular flagella subequal in length; lower ramus thicker than the other, 0.65 times in male and 0.5 times in female the length of carapace Basicerite has a minute spine on distal outer rim. Antennal scale extending as far as tip of antennular peduncle, with a disto-lateral spine which reaches to apex of lamella. Carpocerite stretches to half-way of basal joint of antennular peduncle, 2.5 times as long as wide.

Mandible: molar process subquadrate and more or less indent on masticatory surface. Incisor one with a sharp and a trifle wavy cutting edge. Palp reaches to outer distal end of fourth antennal segment distal segment twice as long as wide measured in the widest region thrice the length of basal one (Fig. 7, *A′*). Maxillulary palp closely resembles that of *Parapenaeopsis cornutus* in general feature, but protuberance lying near base of posterior border of first segment less prominent and distal segment slenderer and longer (Fig. 135, *F*). Endopodite of first maxilliped 5-segmented; ratios in length to the last article: first second 2.5, third 0.5, fourth 1.2. Second maxilliped typical in shape meropodite twice as long as wide, 1.7 times the length of dactylus. Outer maxilliped reaches beyond tip of antennal scale by the last joint, ischium 1.9, merus and propodus 1.1, carpus 1.2 in proportion to dactylus.

First pereiopod reaches to or beyond antero-lateral margin of carapace, movable finger about twice as long as palm. Second surpassing basicerite by half of chela. Third reaches beyond far end of intermediate joint of antennular stalk, proportions in length to dactylus ischium 1.2, merus 2.5, carpus 3.7, palm 0.7. Fourth attains midway of carpocerite, and has a well-developed coxal projection. Fifth extending as far as third cheliped, ratios in length to dactylus: ischium 1.1, merus 3.7, carpus 3.5, propodus 1.8. A basial spine present on each first and second pereiopods. An exopodite present on all thoracic appendages that of third maxilliped reaching to far end of carpo-podite, and that of the last leg somewhat smaller than those of preceding ones.

Endopodite of second pleopod extremely transformed into a segmented stiff appendage a spur-like process at two-thirds of outer edge (Fig. 67

D). Appendix masculina similar to that of *Parapenaeopsis cornutus;* the last segment with hairy distal margin and a tongue-like projection on apical surface (Fig. 63, *C*).

Cardiac plate with 20–22 spinules (Fig. 78, *P*). Cardiac ossicle lunate with strongly convex anterior and rather concave posterior edges, twice as wide as long. Pterocardiac arc-shaped (Fig. 135, *K*). Zygocardiac resembles that of *Parapenaeopsis cornutus* (Fig. 78, *P*). Prepyloric narrowed into a bluntly pointed median tooth in distal half, armed on each postero-lateral rim with about 10 conical teeth which get larger in size posteriorly (Fig. 75, *P* and *V*).

A male, 60 mm long (16.5 mm in carapace-length) and two females, 69.5 mm and 78 mm long (19.9 mm and 23.1 mm in carapace-length) were examined.

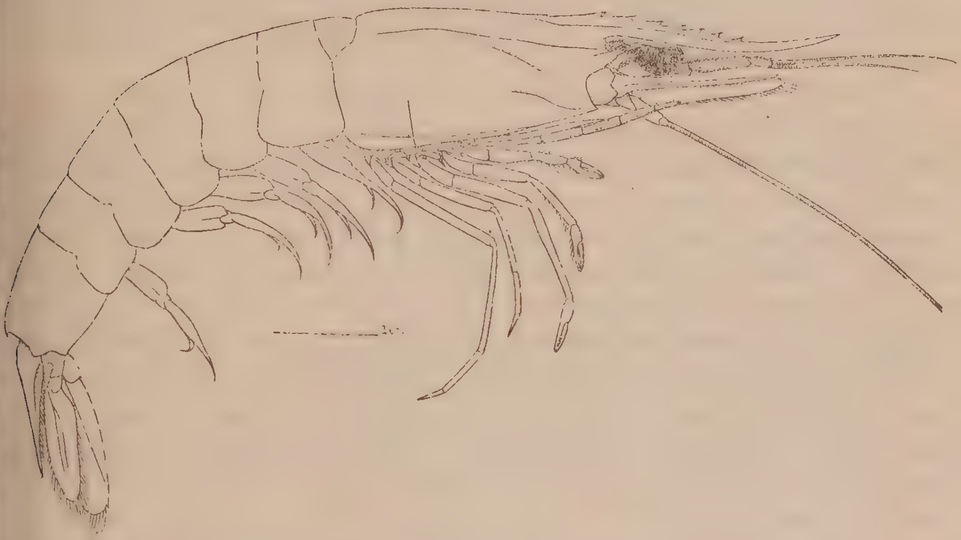

Fig. 138. *Parapenaeopsis hungerfordi* ALCOCK, female, 69.5 mm long.

Locality: Singapore.

Distribution: Hongkong (ALCOCK, BALSS); Singapore; Selangor (BURKENROAD); Amoy (YU).

Note: Our specimens well agree with the brief descriptions given by ALCOCK and YU, and with the figures given by BURKENROAD. From BURKENROAD's description, they differ in having branchio-cardiac groove hardly recognizable and the second pleonic somite entirely rounded dorsally, instead of having the groove faintly well marked and the pleonic somite with very faint compression of the posterior part. But such discrepancies may be probably individual variation within a species.

Parapenaeopsis gracillima NOBILI

(Fig. 136, *G–I*)

Parapenaeopsis gracillima, NOBILI, 1903, p.4, fig. 1; BALSS, 1914, p. 12, figs. 5 and 6; BOONE, 1935, pp. 84–91, Pl. 6, figs. *A* and *B*.
Parapenaeopsis dofleini, BALSS, 1913, p. 234.

Eye rather small, a sixth the length of carapace in longer diameter of cornea. Prosartema attains antero-inner end of eye stalk. Stylocerite reaching below middle of cornea. Antennular flagella different in length; inner ramus 2.2 times the length of carapace. Basicerite has a minute spine directed antero-ventrally at anterior lower angle. Scaphocerite surmounts tip of antennular stalk by its one seventh, 2.5 times as long as wide measured at base, narrowed distally by half, with a small disto-lateral spine which is well exceeded by rounded apex of lamella. Carpocerite extends somewhat beyond far end of first segment of antennular peduucle, thrice as long as wide. Antennal flagella 2.6 times as long as body.

Mandible: molar process with a rectangular and a little depressed masticatory surface, and somewhat medially produced sharp inner distal edge. Incisor one has a notch at two-thirds. Palp attains distal end of third segment of antennal stalk; basal segment deltoid in outline, a third longer than wide, distal one leaf-shaped with rounded apex, twice as long as wide measured in the broadest region, 2.6 times the length of basal one. Maxillula, maxilla and first maxilliped very similar to those of *Parapenaeopsis cornutus* and *P. maxillipedo*. Second maxilliped typical in shape, meropodite 40% of width in length, 1.7 times the length of dactylus. Third one reaches beyond tip of carpocerite by entire dactylus, relative lengths to the last joint: ischium and merus 1.7, carpus 1.5 and propodus 1.4; meropodite the broadest, 2.5 times as long wide; dactylus markedly thin.

First pereiopod surpassing far end of basicerite by half of dactylus. Second extends as far as carpocerite. Third attains tip of antennular peduncle, proportions in length to dactylus: ischium 0.9, merus 2.1, carpus 2.5, palm 0.7. Fourth surpasses tip of antennular stalk by half of dactylus. The last reaching beyond tip of antennular peduncle by distal two segments, ischium 1, merus 3.1, carpus 3.8, propodus 3.5 in proportion to dactylus. All limbs without both basial and ischial spines.

Cardiac plate has 16–18 spinules. Cardiac ossicle triangular in outline with corners rounded, 0.7 times as long as wide measured in the widest region. Pterocardiac subrectangular, thrice as long as wide measured at middle, more or less widened distally, with a projection at each of inner and postero-lateral corners, the projection of inner anterior corner prominent, directed antero-medially, that of inner posterior corner much smaller, directed posteriorly, and that of outer posterior one slender, directed sidewise. Prezygocardiac arc-shaped with somewhat wavy margin. Uro-cardiac typical in shape (Fig. 136, *G a-d*). Zygocardiac with three large teeth on anterior edge, outer two of which are followed by many teeth alined longitudinally and becoming smaller in size backward (Fig. 136, *H*). Prepyloric tapers into a large bluntly pointed median tooth in distal half, with 7–9 small teeth on each posterolateral margin (Fig. 136, *I*).

Three female specimens, 71.0–72.5 mm long (21.0–23.6 mm in carapace-length) were examined.

Locality: 110° 45′ E., 1° 50′ N.

Distribution: Buntal, Borneo (NOBILI); Singapore (BALSS); Durian Straits (0° 29′ N., 104° 47′ E.), 14 fathoms (BOONE).

Note: The specimens dealt with are well in accordance with the description and figures given by BALSS in all important characters. From his Fig. 5, they differ in some points as tabulated below, however, the differences are probably due to the fault of the draughtsman.

Items	Present specimens	BALSS' figure
(1) Longitudinal suture of carapace	reaches to six-eights of carapace	reaching about three-fifths
(2) First leg	surpassing far end of basicerite by half of dactylus	surpassing basicerite by distal half of carpus and entire chela
(3) Fourth leg	reaches beyond antennular peduncle by half of dactylus; palm 0.7 times as long as movable finger	attains middle of second segment of antennular peduncle; palm as long as movable finger
(4) Fifth leg	surmounts antennular peduncle by distal 2 joints	surpassing antennular peduncle by dactylus only.

Parapenaeopsis hardwickii (MIERS)

(Fig. *I*, *C*; 7, *X*; 22, *L*; 29, *A* and *B*; 47, *S*; 63, *G* and *G′*; 75, *M* and *S*; 78, *O*: 134, *C* and *D*; 135, *B*; 139; and 140).

Parapenaeopsis hardwickii, BURKENROAD, 1934b, pp. 60–64, figs., 15 and 16; YU, 1935, p. 165.
Parapeneopsis sculptilis var. *hardwickii*, ALCOCK, 1906, p. 39.
Penaeus hardwickii, MIERS, 1878, p. 300, pl. 17, fig. 1
Penaeus sculptilis (part), HENDERSON, 1893, pp. 448–449.

Post-ocular groove hardly marked. Antennal and branchio-cardiac not recognizable. Orbito-antennal rather defined. Cervical and hepatic ones clearly cut; the former almost straight, attains one-third of the direction toward four-fifths of mid-dorsal line of carapace; the latter sigmoid in outline, reaches a little behind pterygostomian angle. Hepatic spine situated somewhat posterior to epigastric spine. Sixth pleonic somite one-fifth longer than wide, 0.4 times the length of carapace. Telson about 1.1 times the length of sixth pleonic somite, more or less exceeded by apex of inner uropod, furnished in distal quarter with 3 or 4 pairs of so minute dorso-lateral spinules as only made out by a high-power lens.

Eye a fifth the length of carapace in longer diameter of cornea. Prosartema reaching to inner distal end of eye-peduncle. Stylocerite extends to about half-way of basal antennular segment. Antenular peduncle 0.6 times as long as carapace; basal segment with a stout spine at disto-lateral corner; intermediate one ca. 2.6 times the length of the last segment. Antennular flagella variable in length as given later on, but upper ramus a little longer than the lower which is usually about 0.7 times the length of carapace. Basicerite carries a stout spinule directed antero-ventrally on distal outer edge. Antennal scale extending as far as tip of antennular peduncle, thrice as long as wide measured at base, narrowed anteriorly by about two-fifths, with an antero-lateral spine stretching to apex of lamella. Carpocerite attains below middle of cornea, twice as long as wide.

Mandible: molar process bearing slightly concave masticatory surface which is subquadrate in outline, and somewhat dentiform postero-median angle. Incisor one with a notch at two-thirds of cutting edge. Palp reaches to far end of third joint of antennal peduncle, distal segment with rounded apex, 80% longer than wide, 2.5 times the length of proximal segment (Fig. 7, *X*). Maxillulary palp similar to that of *Parapenaeopsis cornutus* and *P. maxillipedo*; basal joint subrectangular, two and half times as long as wide, with a protuberance bearing setae and hairs at disto-median angle besides large protuberances lying on anterior and posterior borders; distal one very minute (Fig. 135, *B*). First maxilliped with narrow scaphognathite; inner distal endite ogival in outline, 2.5 times as long as wide; endopodite five-segmented, proportions in length to the last joint: first 1.2, second 0.3, third 0.4, fourth 1.5. Second inverted J-shaped; meropodite 2.5 times as long as wide; one and half times the length of dactylus. Third depressing, reaching beyond carpocerite by half of dactylus, gradually decreasing in width toward tip anterior to meropodite which is twice the width; proportions in length to dactylus: ischium 2, merus 1.5, carpus and propodus 1.4; exopodite reaches to middle of carpodite.

First pereiopod attains pterygostomian angle. Second a little surpassing far end of basicerite. Third surmounts scaphocerite by a third of chela; proportions in length to dactylus: ischium 1.2, merus 2.3, carpus 3, palm 0.7; meropodite 5.5 times as long as wide. Fourth extending as far second cheliped. Fifth reaching beyond carpocerite by dactylus; proportions in length to dactylus: ischium 1.2, merus 4.2, carpus 4.1, propodus 2.

Appendix masculina is of Type–O_6 (Fig. 63, *G*). Petasma is of Type–M_7 (Fig. 29, *A* and *B*). Thelycum belongs to Type–N_5; anterior median plate trapezoidal in outline with corners rounded, about twice as wide as long measured in the broadest region (Fig. 47, *S*).

Cardiac plate carries 16–18 spinules (Fig. 78, *O*). Cardiac ossicle triangular with corners rounded and somewhat concave posterior border, a little wider than long. Pterocardiac bar-shaped with considerably curved thin inner and outer terminal portions, expanded anteriorly with angular apex at about two-thirds. Prezygocardiac also bar-shaped with produced inner and outer posterior angles. Urocardiac pointed at an angle of ca. 100° at anterior end, bearing a pair of large triangular lateral expansions near anterior end. Zygocardiac very similar to that of *Parapenaeopsis cornutus* with three large sharply pointed teeth on anterior edge and many accessory ones behind them (Fig. 78, *O*). Prepyloric ends in a bluntly pointed large median tooth, each postero-lateral margin has about 18 acute teeth which become gradually larger in size posteriorly, but the rearmost one much smaller than the median (Fig. 75, *M* and *S*).

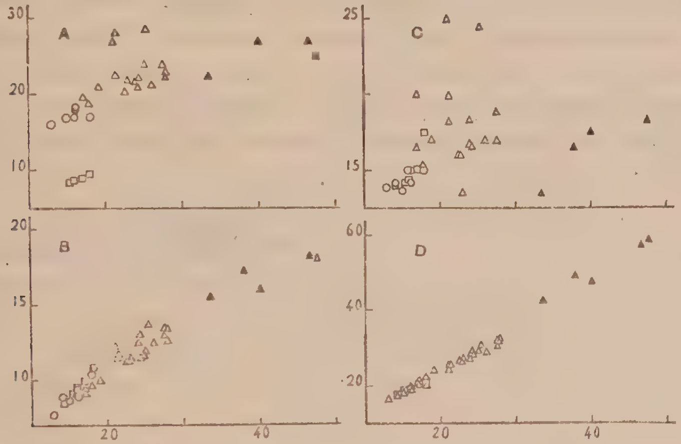

Fig. 139. Dimensions in mm of rostrum (*A*), longer antennular flagellum (*B*), sixth abdominal segment (*C*), and third pereiopod (*D*) in relation to carapace-length. Soft circles (male) and triangles (females), *Parapenaeopsis hardwickii*; soft squares, male of *Parapenaeopsis cultrirostris*; solid triangles, female of *Parapenaeopsis sculptilis*.

The description and figures given above are mostly based on a male

65 mm long (18 mm in carapace-length) and a female, 76.5 mm long (22.8 mm in carapace-length). Besides these, 6 males and 20 females, 46 mm-89.5 mm long (13—27.7 mm in carapace-length) were also examined.

Lacality: Chusan Islands, near Shanghai (collected by Dr. I. Tomiyama and Mr. J. Ozaki); off South coast of Borneo, and Singapore (by Asist. Prof., S. Saitô).

Distribution: Indian Sea? (Miers); Orissa, Ganjam, Madras and Pondichery (Alcock); Singapore, Selangor, Penang and Amoy (Burkenroad); Amoy, Pei-chii-Tchang (Yu).

Note: The rostrum is somewhat variable in length and size of the animal. It is a little longer than carapace in specimens which are smaller than about 20 mm in carapace-length (about 70 mm long), and somewhat shorter than the carapace in the specimens larger than those given above (Fig. 139, *A*). Remarkably enough, three females among examined specimens were found bearing strikingly long rostrum, viz., 1.3 times as long as carapace in two females, 21 mm and 21.2 mm in carapace-length (obtained from Chusan Islands); and 1.14 times in a female, 25.2 mm in carapace-length, (secured off South coast of Borneo)

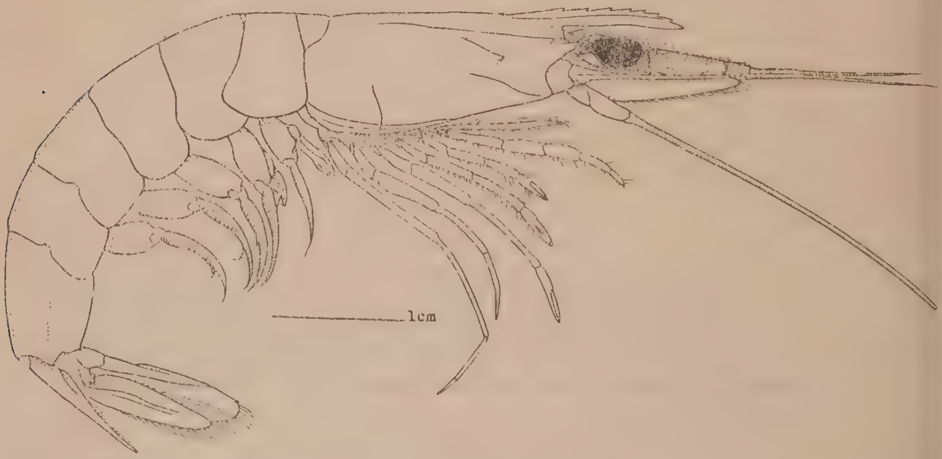

Fig. 140. *Parapenaeopsis hardwickii* (Miers), 76.5 mm in body-length (22.8 mm in carapace-length), female.

The rostral teethe range 7 to 9 in number, mostly 8. Of 26 available specimens, 9 have 7 teeth, 16 have 8 teeth and only 1 has 9 ones.

The antennular flagella appear very variable in length. The upper ramus ranges 0.6 to 1.2 in proportion to carapace-length. But it is usually 0.7 times the lenght of carapace as described already. It would not be without interest to find that the two already mentioned specimens, 21 mm and 25.2 mm long, have both rostrum and antennular flagella longer than those of other specimens of nearly the same size.

The petasmal endopodites of the smallest specimen, 46 mm long, found not yet united together with each other. They are about 2.8 mm long, 7 times as long as wide measured at middle. The basal auriculate appendage of lateral lobe, the twisted disto-lateral horn, and the longitudinal ridge on proximal ventral surface of the lateral lobe well-developed already, but the basal triangular expansion of the median lobe less developed (Fig. 134, *C* and *D*).

The present specimens agree with the accounts of previous investigators (*op. cit*), except some minute points as given below. From MIERS's illustration, they differ in having rostrum less recurved and unarmed, anterior to distal end of the second antennular segment, as well as antennular flagella much longer. From BURKENROAD's Fig. 16, the male copulatory organs of our specimens differ in possession of a simply convex apical margin instead of a wavy one. This difference may be, however, attributed to youngness of the specimens before the writer.

HENDERSON's description (*op. cit.*, p. 448) of *Penaeus sculptilis* agrees with our specimens at least in the following point: "The rostrum is upturned and styliform distally, varying considerably in length, but usually a third or more of its length longer than the antennular peduncles;—". But further he describes "All the abdominal segments may be carinated, but the first three indistinctly so" (this corresponds to *Parapenaeopsis sculptilis*), "and sometimes not at all" (this corresponds to *Parapenaeopsis hardwickii*). Such being the case, he apparently confounded these two species.

Parapenaeopsis sculptilis (HELLER)

(Fig. 7, *B'*; 47, *T*; 75, *O* and *U*; 79, *A*; 135, *I*; 139).

Parapenaeopsis sculptilis, NOBILI, 1903, p.5; BALSS, 1914, p.11; BOONE, 1935, pp. 80 84, text-fig., 4, pl. 20.

Parapeneopsis sculptilis, ALCOCK, 1906, pp. 37 38, pl. 7, figs., 22, 22*a-d*; BURKENROAD, 1934, pp. 59-60.

Penaeus, sculptilis, HELLER, 1865, p. 122, pl. 11, fig., 1; MIERS, 1880, p. 457; DE MAN, 1888, p. 286.

Penaeus sculptilis (part), HENDERSON, 1893, pp. 448-449.

Post-ocular groove rather defined. Orbito-antennal, cervical, and hepatic ones well-marked, former two of which are broad and tomentous, the rest narrow, somewhat sinuous and inclined antero-ventrally, becoming somewhat wider and obtuse posteriorly but traceable to three-fourths of carapace, reaching some distance toward pterygostomian angle, with a sharp lower edge anterior to hepatic spine. Supra-orbital angle minutely spiniform. Hepatic spine located a little behind epigastric one as in *Parapenaeopsis hardwickii*. Pleonic segments from fourth to sixth have a minute spine dtrected backward at posterior end of each of their dorso-median carina, the spines of fourth and fifth segments subequal in size but much smaller than that of sixth segment. Sixth pleonic segment as long as wide measured at middle, a trifle less than a third the length of carapace, with postero-inferior angles minutely dentiform, bearing three cicatrices. Telson without lateral spinules, half times the length of carapace. Eye one-sixth to one-seventh the length of carapace in longer diameter of cornea. Prosartema, stylocerite, antennular peduncle very similar to those of *Parapenaeopsis hardwickii.* Antennular flagella different in size and probably in length; upper ramus thinner and longer than the other, 0.38–0.44 times the length of carapace. Second antenna equals to that of *Parapenaeopsis hardwickii* in configuration of basicerite and scaphocerite, but carpocerite extends as far as distal end of first segment of antennular peduncle, somewhat less than thrice as long as wide.

Mouth-parts closely resemble those of *Parapenaeopsis hardwickii* except the following points. Distal segment of mandibular palp less narrowed distally, 2.3 times the length of proximal one (Fig. 7, *B'*) Endopodite of first maxilliped five-jointed, proportions in length to th last one: first 1, second 0.3, third 0.4, fourth 1.2. Third maxilliped with relatively shorter dactylus, proportions in length to ultimate joint ischium 2.5, merus 1.9, carpus and propodus 1.7.

First limb reaching to or beyond pterygostomian angle by movabl finger. Second surmounts distal margin of basicerite by half or entir chela. Third surpassing carpocerite by about half or entire chela, pro portions in length to dactylus: ischium 1.1, merus 2.3, carpus 3.6, pal 0.8. Fourth extending to or beyond basicerite by dactylus. Fift reaches to or beyond carpocerite by dactylus, proportions in length t the last article: ischium 1.5, merus 5.3, carpus 4.7, and propodus 2.

Thelycum: anterior median plate broad, semicircular in outline somewhat less than twice as wide as long. Posterior one with a tuft o long hairs at middle (Fig. 47, *T*).

Stomodaeal ossicles closely resemble those of *Parapenaeopsis hard wickii*, but appear different in the following points. Cardiac plate h 18–20 spinules alined longitudinally. Cardiac ossicle characterized b bearing considerably indent antero-lateral margins, one and half times a wide as long. Pterocardiac furnished with a sinuate anterior edg Prepyloric carries about 11 acute teeth on each postero-lateral margi (Figs. 75, *O* and *U*; 79, *A*; and 135, *I*).

The description and figures given above are based on five females 104.2–133.6 mm long (33.5–47.5 mm in carapace-length), obtained fro Singapore fish market.

Distribution: Java (HELLER); W. Borneo (MIERS); Mergui Archi pelago (De Man); Buntal Bombay (Nobili); G. of Martaban, Off Cochin coast; Bombay, Mergui, Penang, Hooghly R. Hongkong; Orissa and Ganjam; Palk Strait (Alcock); Penang (Burkenroad, and Boone).

Note: All the specimens examined are in harmony with the descriptions and illustrations given by Heller, De Man, Alcock, Burkenroad, and Boone, exclusive of the following respects. The figure given by Heller differs in longer fourth pereiopods and that given by Alcock in shorter one.

Boone's specimens have, according to her description and figures, no spinules at distal ends of dorso-median carinae of the fourth and fifth abdominal segments, as represented in Heller's Fig. 1, and have remarkably slender (1.7 times as long as wide) sixth abdominal segment.

The present species is so closely related to *Parapenaeopsis hardwickii* as sometimes confounded with it. However, it is easily separable from the latter in possession of the following particulars, viz., (1) rostrum as well as antennular flagella in relative length against carapace, smaller (Fig. 139, *A* and *B*), (2), epigastric spine standing at a fifth of carapace, (3) terga of first and second of pleonic segments with shallowly canaliculated dorso-median carinae, (4) eye a seventh the length of carapace in longer diameter of cornea, (5) carpocerite reaching to distal end of first antennular segment, and (6) thelycum with semicircular anterior plate and a tuft of long hairs at middle of posterior plate.

Genus *Trachypenaeus* Alcock (emend)

Trachypeneus, Alcock, 1901, p. 15; 1906, p. 43; Burkenroad, 1934*a*, pp. 94-96.
Trachypenaeus, De Man, 1911, pp. 87-88; Balss, 1914, p. 11.

Rostrum with dorsal teeth only. Carapace with short longitudinal sutures and rather marked grooves. Abdomen dorsally carinated. Telson pointed at tip, bearing no immovable dorso-lateral spines. Mandibular palp foliaceous, broad. Maxillulary palp unsegmented. Exopodite present on all thoracic appendages. Petasma symmetrical (usually with large disto-lateral projections). Thelycum anteriorly provided with a broad tumid plate.

Pleurobranchiae lacking on last two thoracic somites. An arthrobranchia on penult thoracic somite, and one on the last. Mastigobranchiae of first and second pereiopods present or absent, but those of third lege always present (Table 6, *J* and *L*).

In addition to these, the annexed traits appear common to *T. curvirostris* and *T. asper*. Appendix masculina is of Type-O_2. Zygocardiac ossicle belongs to Type-R_3.

The branchial formula given by Alcock (1906, p. 43) holds good for *T. curvirostris* and two Atlantic species: *T. constrictus* and *T. similis* (BURKENROAD, 1934a, p. 94), but not for all other known Indo-pacific species (SCHMITT, 1931, p. 265). In this connection, it should noticed that BURKENROAD (*loc. cit.*) split the present genus into two subdivisions, 1 and 2. The former is characterized by having mastigobranchia on the first and second pereiopods, and the latter by having no ones on such pereiopods. *T. curvirostris* was referred by BURKENROAD to the second subdivision. But the present specimens which should go with the name of the same species are found to have the branchia in question on the anterior two pereiopods, besides having it on the third limb.

Within the present genus, six Indo-pacific forms: *T. curvirostris* (STIMPSON), *T. granulosus* (HASWELL), *T. anchoralis* (BATE), *T. asper* ALCOCK, *T. salaco* DE MAN and *T. pescadreensis* SCHMITT [with which *Trachypenaeus* sp. MAKI and TSUCHIYA (1923, pp. 46–47, pl. 4, fig. 3) is probably identical], and two Atlantic ones: *T. constrictus* (STINPSON) and *T. similis* (SMITH), have been put on records. Of these, *T. salaco* has been represented by male, and *T. granulosus* and *T. pescadreensis* by female only. All the forms may be discriminated as given in the following key.

Key to the species of *Trachypenaeus*

A_1 Mastigobranchiae present on three anterior pereiopods; fifth legs not extending t tip of antennal scale; petasma with a pair of large processes directed sidewise a disto-lateral angles; anterior plate of thelycum subrhombic, without both median ridg and posterior tongue-like projection ....*T. curvirostris*

A_2 Mastigobranchiae present on third pereiopods only; fifth pereiopods reaching wel beyond tip of antennal scale

  I (for male)

    B_1 Disto-lateral projections of petasma straight, directed sidewise ....*T. asper*

    B_2 Disto-lateral projections of petasma L-shaped: directed anteriorly in distal half ....*T. anchoralis*

    B_3 Disto-lateral projections of petasma produced sidewise with terminal portion directed antero-medially ....*T. salac*

  II (for female)

    C_1 Anterior plate of thelycum without a prominent longitudinal median ridge

      D_1 Anterior plate of thelycum without a large tongue-like median protuberance on posterior margin

        E_1 Rostrum considerably inclined upward with straight inferior border anterior plate of thelycum semicircular in outline; posterior one somewhat convex or flattish on outer surface ....*T. asper*

        E_2 Rostrum almost straight with slightly recurved lower edge; anterio plate of thelycum subpentagonal in outline with broadly rounded apex posterior one medially depressed on outer surface ....*T. anchoralis*

      D_2 Anterior plate of thelycum with a large median tongue-like protuberanc on posterior border ....*T. glanulosus*

C_2 Anterior plate of thelycum carries a prominent longitudinal ridge
T. pescadreensis.

Trachypenaeus curvirostris (STIMPSON)

(Figs. 1, *V*; 4, *A*; 7, *I'*; 9, *B*; 21, *A*; 32, *I* and *J*; 41, *A-H*; 47, *K*; 51, *A-G*; 59, *A*; 68, *K-N*; 75, *Q* and *W*; 79, *C*; 141; 142).

Trachypenaeus curvirostris, BALSS, 1914, p. 11; 1924, p. 44; PARISI, 1919, p. 64; MAKI and TSUCHIYA, 1923, pp. 45-46, pl. 3, fig. 1; HIRUMA, 1925, pp. 425-426; fig. 8; SCHMITT, 1926, pp. 353-358, pl. 63, fig. 3; URITA, 1926, pp. 22-23; YOKOYA, 1930, p. 526; 1933, pp. 9-10; 1935, p. 262; YU, 1935, pp. 166-167; OSADA, TANIZAKI and NAKAZAWA, 1936, p. 8, pl. 4, middle; YOSHIDA, 1941, pp. 16-17, text-fig. 9, pl. 3, fig. 3.

Trachypeneus curvirostris, ALCOCK, 1905, p. 523.

Parapenaeus curvirostris, RATHBUN, 1902, p. 38.

Penaeus (Trachypenaeus) curvirostris, DE MAN, 1907, pp. 436-439, pl. 33, figs. 56-58.

Penaeus curvirostris, MIERS, 1878, p. 307 (in key); ORTMANN, 1890, p. 451, pl. 36, fig. 4, a, b; KISHINOUYE, 1900, pp. 23-25, pl. 6, fig. 4, pl. 7 fig. 10; DOFLEIN, 1902. p. 631.

Penaeus anchoralis, BATE, 1881, p. 181; 1888, pp. 258-261, pl. 35, fig. 1" (part except female from the Arafura Sea); DE MAN, 1911, pp. 88-90 (part); 1913 (plates), pl. 8, fig. 28.

Rostrum hardly reaching to far end of second segment of antennular peduncle or to tip of the peduncle. Epigastric spine inserted at two-sevenths of carapace. Hepatic just below epigastric spine. Sixth pleonic somite a little longer than wide measured at middle, about 2.3 times the length of carapace, and has a spinule directed backward at each postero-inferior angle. Prosartema extends forwards as far as eyestalk. Stylocerite attains about midway of basal segment of antennular peduncle. Antennular flagella subequal in length, 0.6–0.7 and 0.45–0.6 times as long as carapace in male and female respectively (Fig. 142, *A*). Scaphocerite almost reaches to tip of antennular peduncle, 2.7 times as long as wide measured in the widest region, marrows anteriorly by half, with a disto-lateral spine which extends as far as apex of laminar portion.

Mandible: molar process in possession of flattish masticatory surface which is subquadrate in outline, with inner masticatory edge sharper than the other and somewhat produced medially. Incisor one has a triangular notch at distal one-third. Palp reaching to distal end of fourth segment of antennal peduncle; basal segment triangular in outline; the distal one rather narrowly rounded at apex, strongly swollen in three-fourths of outer border, 0.9 times longer than the greatest width, 2.5 times the length of basal one (Fig. 7, *I'*). Maxillulary palp subrectangular, about twice as long as wide, and has a protuberance on each of anterior (about middle), and posterior (near base) borders as well as at disto-lateral angle, besides a spinous seta at disto-median angle. Maxillary palp rather thickened, twice as long as wide, with a pointed protuberance at disto-median angle. First maxilliped with inner distal lacinia ogival in outline, 2.4 times the width; endopodite five-segmented, proportions in length to the last joint: first 1, second 0.4 third 0.6, fourth 1.5; exopodite 8 times as long as wide measured at middle, with almost straight outer edge, bluntly pointed at apex. Second inverted J-shaped, merus twice as long as wide, one and half times the length of dactylus. Third as usual in general aspect, reaching slightly beyond far end of basal segment of antennular peduncle; merus, carpus and propodus subequal in length; propodus one and half times the leng th of dactylus.

Appendix masculina is of Type–O_2 (Fig. 59, *A*).

Copulatory organs of both sexes well agree with KISHINOUYE's Fig 10. (Fig. 32, *I*, and *J*, and 47, *K*).

Cardiac plate has 30–33 equidistant spinules alined longitudinally (Fig. 79, *C*). Urocardiac ossicle with almost straight anterior margin bearing bluntly pointed process directed sidewise on each subtermina lateral edge. Prepyloric ends in a rather large median tooth, arme along each post-lateral margin with about 23 pointed teeth which ge gradually smaller backward, and proximal about 10 of which are minut (Fig. 75, *Q* and *W*).

The description is mostly based on the largest male, 81.1 mm lon (22 mm in carapace-length) obtained from Tokyo fish market, and th largest female, 98.4 mm long (30 mm in carapace-length), from Toi (Inland Sea). In addition to these, 43 males and 62 females, 30.1 98 mm long (8.2–29.2 mm in carapacial length), were also examined.

Locality: Tyôshi and Hatazawa, Chiba Pref.; Tokyo (fish market) Miya, Aichi Pref.; Ushimado, Okayama Pref.; Tomo, Hiroshima Pref. Shimonoseki, Yamaguchi Pref.; Sashiki, Kumamoto Pref.; Toyamawan.

Distribution: Inland Sea of Japan (DE MAN); off Yokohama (5–2 fathoms) (BATE); Nagasaki, Dzushi (50–100 m), Ito and Hatsushim (150 m), Tsu, Hong Kong, Tshifu (China), Fusan (Korea), Tsingta (BALSS); Awomori to Kagoshima (Kishinouye); Yokohama (DOFLEIN (MAKI and TSUCHIYA); Todo-saki to Uwazima (36–163 m); Boshû, Sagar Okitsu, Suruga, Tokyo Bay (PARISI); Hakodate, Aomori, Nagasa (RATHBUN); Siranui (Kumamoto) OSADA, TANIZAKI and NAKAZAWA Tsingtao (URITA); Off Frazer Island (Queensland) (32–33 fathom (SCHMITT); Amoy, Chefoo (YU); East caost (Southward to Huzan) an West coast of Tyôsen (YOSHIDA); Tomo, Ushimado (Inland Sea of Japan (HIRUMA); Tokyo, Sagami, Maizuru (ORTMANN).

Note: The specimens at the author's disposal agree well with th descriptions and figures given by KISHINOUYE) (1900) and DE MA (1907), except that the minute ischial spines of the first pereiopods, whic are overlooked by them (KISHINOUYE, p. 24; DE MAN, p. 438), are found to exist in the present material.

With regard to the rostrum, the curveture is subject to a considerable variation with age and sex. The apparatus appears simply straight in specimens smaller than about 50 mm long in male and 58 mm long female (Fig. 141, *B*, *E* and *F*), but recurved in distal half in larger specimens than those given above (Fig. 141, *A*, *C* and *D*). It becomes gradually stronger in degree of the inclination with advance of age in both sexes, although it is, as a whole, less ascending in male.

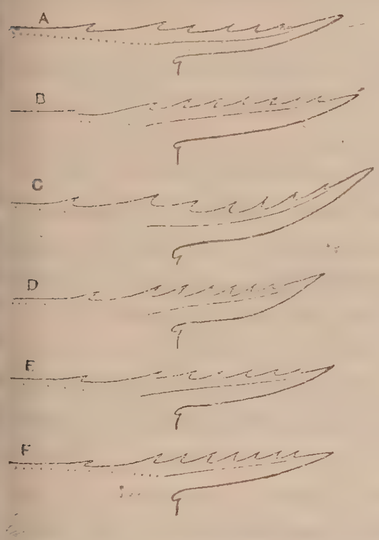

Fig. 141. Showing age-variation of rostrum of *Trachypenaeus curvirostris*. *A*, 81 mm long (22 mm in carapace-length), ×1.75; *B*, 50 mm long (13.2 mm), ×3.25; *C*, 98 mm long (29.5 mm), ×1.55; *D*, 70 mm long (20 mm), ×2; *E*, 58 mm long (16 mm), × 2.5; *F*, 44 mm long (11.6 mm), ×3.25. *A* and *B*, male; *C*–*F*, female.

The rostral spine (excluding epigastric spine) vary from 6 to 8, but mostly 6 in number. Of 105 specimens, 53 have 6, 48 have 7, and only 4 have 8 spines.

The antennular flagella are sexually dimorphic: those of male are a little longer than those of female as set forth already. The relative length, as referred to carapace, is almost linear in trend in smaller specimens than about 22 mm in carapace-length (ca. 77 mm long) in both sexes. But the rate of growth becomes less in larger females than those given above (but males as large as such are not represented in the present material). It is worth mentioning that the flagella of the two females obtained off South coast of Borneo have somewhat smaller relative growth than those of Japanese specimens (Fig. 142, *A*). But such difference seems to be due to local variation.

The lengths of the third and fifths pereiopods are proportional to the carapace-length. Both the limbs are equally about one and half times the length of carapace irrespective of sex and age so far as the present study goes. As regards these items, the two Bornean specimens display no marked difference (Fig. 142, *B* and *C*).

Trachypenaeus asper ALCOCK

(Figs. 7, *H'*; 32, *K* and *L*; 47, *L*; 59, *B*; 75, *R* and *X*; 79, *D*)

Trachypeneus asper, ALCOCK, 1906, pp. 43-44, pl. 9, figs. 28, 28 *a-b*.

Dorso-median carinae of fourth and fifth pleonic somites not incised posteriorly, each of which ends in a spinule. Sixth pleonic somite as long as wide, about 0.4 times the length of carapace, furnished with a minute spine at each postero-inferior angle. Telson a little less than thrice as long as wide measured in the broadest region, somewhat more than half of carapace, armed with two pairs of movable dorso-lateral spinules, those of anterior pair inserted at a quarter, much smaller than those of the posterior one lying at a seventh. Eye has a depressed and sharply pointed process on upper distal edge of basal peduncle, two-sevenths the length of carapace in longer diameter of cornea. Prosartema reaches to anterior end of eyestalk, extends as far as stylocerite. Antennular peduncle surpassing tip of rostrum by third joint, basal joint has a stout disto-lateral spinule directed antero-laterally; intermediate joint twice the length of the third. Antennular flagella subequal in length and size, and as long as stalk, 0.64–0.76 times the length of carapace. Basicerite possesses a spinule on distal outer margin. Scaphocerite reaching slightly beyond tip of antennular peduncle, 2.5 times the width measured near base, distally narrows by two-fifths, armed with a disto-lateral spine which extends as far as apex of lamella. Carpocerite streches below middle of cornea, 2.5 times as long as wide.

Mouth-parts much alike to those of *Trachypenaeus curvirostris* (Fig. 7, *H′*), except that third maxilliped reaches to far end of second segment of antennular peduncle.

First pereiopod reaches distal end of first joint of antennular peduncle, second one to tip of the peduncle. Third surpassing tip of antennular peduncle by about one-eighth of carpus and entire chela taken together, proportions in length to movable finger: ischium 1.7, merus 4.4, carpus, 7.1, palm 1.1. Fourth extending as far as third maxilliped. Fifth reaches distal end of antennular peduncle by half of propodus and dactylus, proportions in length to dactylus: ischium 1.1, merus and carpus 3.4, propodus 1.7. A basial spine present on each of first and second pereiopods, and an ischial one on first leg.

Appendix masculina very similar to that of *T. curvirostris* in general configuration; distal piece subrectangular, half times the length of proximal one (Fig. 59, *B*).

Petasma T-shaped, bearing a pair of distal pointed wing-like processes (Fig. 32, *K* and *L*).

Thelycum closely related to that of *T. curvirostris*, but semicircular in outline in anterior plate, and less emarginate on anterior border of posterior plate (Fig. 47, *L*).

Cardiac plate with 35–39 equidistant spinules longitudinally arranged in a row (Fig. 79, *D*). Cardiac ossicle cardiform, two-fifths wider than long. Pterocardiac slender, bar-shaped, somewhat wavy, tapering sidewise into a bluntly pointed tip. Prezygocardiac rather thin, crescentic, with anterior border convex. Urocardiac as usual in shape, with rather narrowly rounded anterior apex. Zygocardiac has three large pointed teeth on anterior edge, outer two of which are followed by rather closely set acute teeth which gradually get smaller backward (Fig. 79, *D*). Prepyloric provided along each postero-lateral edge with about 13 conical teeth increasing in size posteriorly (Fig. 75, *R* and *X*).

A male, 60 mm long (16.7 mm in carapace-length), and two females, 65 mm and 67 mm long (18.9 mm and 19.5 mm in carapace-length) were examined, on which the present description and the illustrations are based.

Locality: Off South coast of Borneo.

Distribution: Camjam coast (20–35 fathoms); Andamans (60 fathoms); Persian Gulf.

Note: My specimens differ from Alcock's description and illustrations in the following points, viz.; (1) rostral spines, except epigastric one, 8 in number; (2) antennular flagella as long as its peduncle; (3) anterior plate of thelycum semicircular in outline; (4) scaphocerite reaching slightly beyond tip of antennular peduncle; and (5) posterior end of each fourth and fifth abdominal segments bearing a minute spine. But they coincide with the description and illustrations in most important characteristics. Therefore they are referred to the present species.

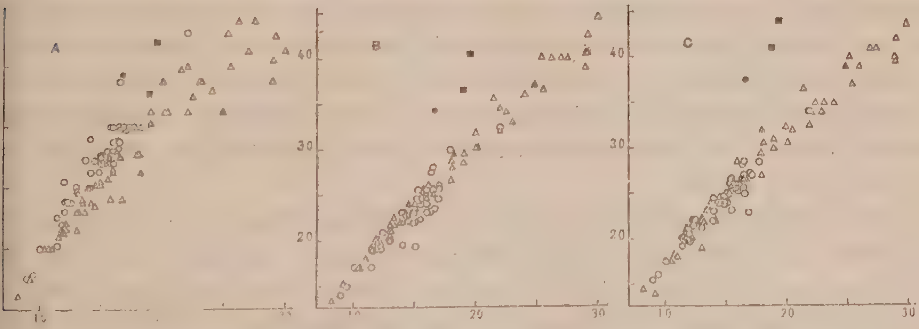

Fig. 142. *Trachypenaeus curvirostris* (soft marks and solid triangles), *Trachypenaeus asper* (solid circles and squares). *A*, antennular flagella; *B*, third pereiopods, *C*, fifth pereiopods. Circles, male; triangles and squares, females. Solid triangles, *T. curvirostris* obtained off South West of Borneo.

Trachypenaeus asper Alcock closely allied to *Trachypenaeus curvirostris* (Stimpson) in general feature. Schmitt (1926) united the latter regarding the rostral characters of the former as intraspecific variation of the latter. But the characters in question do not appear to the writer as mere variations within one species since they exhibit distinct two types. Besides, the following many characteristics valuable for discrimination of *T. asper* from *T. curvirostris* lead the writer to believe that these two forms are well-defined: (1) postrostral crina less conspicuous; (2) cervical groove hardly marked; (3) dorso-median carina of fourth and fifth pleonic segments not insiced posteriorly, bearing a spinule on each distal extremity; (4) telson armed with only two pairs of dorso-lateral spinules; (5) third maxillipeds and all pereiopods considerably slenderer and much longer (Fig. 142, *B* and *C*); (6) anterior plate or thelycum semicircular in outline, and anterior border of posterior plate less excavated; (7) cardiac plate with larger number of spinules; (8) mastigo-branchiae of first and second pereiopods absent.

Genus ***Parapenaeus*** SMITH (emend)

Parapenaeus, SMITH, 1885, p. 170; BOUVIER, 1908, pp. 101–102; DE MAN, 1911, pp. 77–79; BALSS, 1914, p. 10; 1925, pp. 227–228; PESTA, 1918, p. 42; SCHMITT, 1926, pp. 323–324; BURKENROAD, 1934*a*, pp. 107–108.
Parapeneus, ALCOCK, 1901, p. 14; 1906, pp. 32–33.

Rostrum toothed dorsally. Carapace with a longitudinal suture on either side extending from orbital to posterior margins, and a vertical one across branchiostegite above second pereiopods. Antennal, epigastric and hepatic spines present. Branchiostegal spine usually present. Abdomen with dorso-median carina posteriorly. Telson acute at apex, provided with a rather shallow dorsal groove along median line, a pair of lateral prongs and a pair of inmovable lateral spines. Antennular flagella of moderate length. Maxillulary palp unsegmented. Exopodite present on all thoracic appendages, that of all maxillipeds markedly developed but that of all pereiopods minute, especially that of the last two limbs hardly visible.

A pleurobranchia present on each thoracic somite from second to seventh. An arthrobranchia exists on the first and seventh, but that of the former is vestigial, and two ones on the somites from second to sixth. A podobranchia present on the second only. A mastigobranchia present on first two maxillipeds and pereiopods (See Table 6, *H*), tha of third limb present or absent.

In addition to these, the following characters—probably very valuabl for delimitation of the present genus—are found common to four specie dealt with.

First pereiopod has a basial and an ischial spines. Petasma is of Type–M_6, thelycum Type–N_5, and appendix masculina Type–O_4. Pterocardiac belongs to Type–Q_3, zygocardiac Type–R_2.

In regard to the exopodites, ALCOCK (1906, p. 30) mentions: "n exopodites on any of the thoracic legs", PESTA (1918, p. 45): "Alle

Pereiopoden ohne Exopoditen", and Burkenroad (1934 *a*, p. 107): "exopodites well developed on the posterior two pairs of maxillipeds, minute but present on the walking legs". All the present specimens, referable to four species as given later, well agree with the category given by Burkenroad, and the writer is inclined to consider that the strikingly minute exopodites of the pereiopods were oversighted by Alcock and Pesta.

The demarkation of the genus, *Parapenaeus*, from the genera, *Metapenaeopsis* and *Metapenaeus*, is not very clear when based on the branchial and exopodal traits. Since the traits of these three genera are identical with each other except for the following. The mastigobranchia of the third pereiopod seems occasionally present as set forth above, and the exopodites of all the pereiopods are very minute in size in *Parapenaeus*. However *Parapenaeus* may be well defined from both of the allied genera, *Metapenaeopsis* and *Metapenaeus*, when based on the following characteristics, which have been left unnoticed by previous investigators, besides the ordinary generic distinctions, viz., the features of appendix masculina, pterocardiac and zygocardiac ossicles, and processes–*a*, *b*, and *c* of the petasma. Moreover, it is discernible from *Metapenaeopsis* in lacking basial spine on third maxillipeds and second pereiopods, and having shorter stylocerite; from *Metapenaeus* by possession of no basial spine on second and third pereiopods.

Parapenaeus is also near to *Parapenaeopsis*, but it is easily separable from the latter by having the annexed features: longitudinal sutures of carapace attain posterior edge of the apparatus; telson carries a pair of large immovable spines; second pereiopods without basial spines; petasma is of Type–M_6, appendix masculina Type–O_4, pterocardiac ossicle Type–Q_3, and zygocardiac Type–R_2; and a pleurobranchia present on seventh thoracic somite.

The species of *Parapenaeus* are seven⁽¹⁾ at present in number including two new species: *P. fissurus* (Bate), *P. investigatoris* Alcock, *P. longipes* Alcock, *P. lanceolatus* sp. nov., *P. sextuberculatus* sp. nov., *P. longirostris* (Lucas), and *P. americanus* Rathbun, first five of which are Indo-Pacific and the rest Atlantic inhabitants. They may be distinguished according to the following key.

A_1 Branchiostegal spine present; fifth pereiopods considerably exceeded by antennal scale
  B_1 Branchiostegal spine located on anterior margin of carapace
    C_1 Sixth abdominal segment less than twice the length of the fifth
      D_1 Process-*a* of petasma bifurcate, directed sidewise

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(1) Schmitt, 1926, pp. 323-324; Burkenroad, 1934 *a*, pp. 107-108.

E_1 Petasma: process-*a* rather slender, symmetrically bifurcate; process-*b* long, sharply pointed, well surmounting process-*c*; process-*d* present. Thelycum consists of anterior, intermediate and posterior plates, subpentagonal in general outline with rather narrowly rounded apex, medially strongly depressed, and has a pyramidal tuber on each side of intermediate plate ....*P. fissurus* (Bate).

E_2 Petasma: Process-*a* broad, asymmetrically bifurcate; process-*b* short, abruptly pointed at apex, produced as far as process-*c*; process-*d* absent. Thelycum made up of anterior and posterior median bosses, and two pairs of anterior and posterior lateral ones; anterior median boss the largest of all, inverted cardiform, convex on ventral surface ....*P. sextuberculatus* sp. nov.

D_2 Petasma: process-*a* simply pointed, directed disto-laterally; process-*b* well developed, directed antero-dorsally, with acute tip bent anteromedially; process-*d* minute. Female unknown ....*P. lanceolatus* sp. nov.

C_2 Sixth abdominal segment a little more than twice the length of the fifth ....*P. americanus* Rathbun(1)

B_2 Branchiostegal spine situated a little behind frontal margin of carapace

F_1 Rostrum reaching about distal end of first antenular segment; sixth abdominal segment somewhat more than twice the length of the fifth. Petasma without apical projections, process-*e* very thin.........*P. investigatoris* Alcock.

F_2 Rostrum about horizontal, slightly sigmoid, reaching far end of second antennular segment; sixth pleonic somite a little less than twice the length of the fifth; petasma with a pair of large apical projections directed outward in distal half, process-*e* broader than long ....*P. longirostris* (Lucas)(2)

A_2 Branchiostegal spine absent; fifth pereiopods reach beyond tip of antennal scale by dactylus ....*P. longipes* Alcock(3)

Parapenaeus fissurus (Bate)

(Figs. 7, *C′*; 21, *E*; 28, *A-C*; 47, *P*; 61, *B* and *B′*; 75, *A* and *G*; 78, *G*; 143, *A* and *E*)

Parapenaeus fissurus, De Man, 1911, pp. 79 80; Balss, 1914, pp. 10-11, fig. 4; 1924, p. 44; Stebbing, 1914, pp. 19-20, pl. 69; Yokoya, 1933, p. 8; Yoshida, 1941, p. 17, text-fig. 10, pl. 4, fig. 1.

Parapeneus fissurus, Alcock, 1905, p. 520; 1906, pp. 31-32, pl. 5, fig. 16, 16a, b.

Penaeus fissurus, Bate, 1888, pp. 263-266, pl. 36, fig. 1.

Carapace with hardly marked orbit-antennal, cervical and hepatic grooves; the last one sigmoid, bearing well-defined lower edge in anterior half, attains anterior margin of carapace and a little above pterygostomian angle. Supra-orbital angle forms a small spiniform process. Epigastric, antennal, hepatic and branchiostegal spines present; first three of which are subequal in size, and the last very minute and located at end of hepatic groove. Epigastric spine situated at a third of carapace, hepatic slightly in front of a line vertical through epigastric spine and a trifle below a level horizontal through antennal spine. Sixth pleonic somith 1.5 times as long as wide measured at middle, 1.8 times the length of fifth, and 0.6 times the length of carapace, and has a spinule at each postero-inferior angle in addition to that placed at posterior end of dorso-median carina. Telson sharply pointed at tip, attains apex of inner uropods, bearing a small triangular expansion at a third of each lateral edge, and has a pair of fixed lateral spines at two-thirds.

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(1) Rathbun, 1902, p. 102, pl. 2 (upper).

(2) Pesta, 1918, pp. 42-46, figs. 8 and 9; Bouvier, 1908, pp. 102-105; pl. 16, fig. 22; Burkenroad, 1934 *a*, pp. 108-116.

(3) Alcock, 1906, pp. 33-34, pl. 6, fig. 18.

Eye-stalk carries a deltoid scale directed anteriorly on distal upper border. Prosartema extends as far as anterior end of eye-stalk. Stylocerite reaches to half-way of basal segment of antennular peduncle. Antennular peduncle: basal joint possesses an acute spine directed forward at disto-lateral angle, and a hardly recognizable one on ventro-median margin; second cylindrical, 1.8 times the length of third one. Basicerite has a small spine on distal outer margin. Scaphocerite reaches about middle of the last joint of antennular peduncle, 3.5 times as long as broad measured near base, narrowed distally by half, with a disto-lateral spine which extends as far as apex of lamella. Carpocerite reaches tip of stylocerite.

Mandible: molar process flattish on masticatory surface which is subquadrate in outline and stained vermilion (in alcoholic specimens), produced postero-medially at postero-median angle of masticatory edge. Incisor process sharp, with a deep notch at two-thirds of cutting rim. Palp reaches base of fourth segment of antennal peduncle; distal joint with rather truncate apex, strongly excavated at disto-lateral angle, 1.7 times as long as wide, 2.3 times the length of basal one (Fig. 7, *C'*). Maxillulary palp unsegmented, subrectangular, with a large protuberance on each anterior (about middle) and posterior (near base) borders, about twice as long as wide (Fig. 143, *A*). Maxilla is of Type-G_1, with ear-shaped exopodite. First maxilliped: inner distal endite 2.5 times as long as wide, rounded at apex; palp 5-segmented, proportions in length to the last joint: first 2, second 0.4, third 0.7, fourth 1.6; exopodite narrow, with lateral straight and parallel margins, and distal antero-laterally curved one. 6 times as long as wide. Second normal in shape; meropodite 2.5 times as long as wide, twice the length of dactylus. Third reaches to distal end of intermediate segment of antennulr peduncle, ischium 1.3, merus, carpus, propodus 1.5 in proportion to dactylus; propodus furnished with a thicket of short hairs in distal fourth of vental surface.

First pereiopod reaching to middle of carpocerite, and second slightly beyond the apparatus. Third extends as far as third maxilliped, relative length to movable finger: ischium 1, merus 2.3, carpus 3, palm 0.9. Fourth reaches to or slightly beyond far end of first segment of antennular peduncle. Fifth stretches as far as third maxilliped, proportions in length to dactylus: ischium 1.3, merus and carpus 3.3, propodus 2.

Appendix masculina is of Type-O_4, provided on anterior surface of proximal piece with a prominent ridge which is thrice as long as wide and rounded on distal border (Fig. 61, *B*).

Petasma is of Type-M_6; process-*a* prominent, symmetrically bifurcate at apex directed sidewise; process-*b* rather slender, sharply pointed at tip, directed dorsally, with anterior margin considerably curved posteriorly; process-*c* bluntly pointed, directed dorsally, well exceeded by tip of process-*b*; process-*d* conspicuous, acute, directed anteriorly; process-*e* slightly wider than long (Fig. 28, *A-C*).

Thelycum pentagonal in outline, made up of closely set anterior, intermediate, and posterior plates, strongly depressed medially backward to middle of anterior plate; anterior plate deltoid in outline with rounded apex; intermediate one remarkably elevated on both sides (Fig. 47, *P*).

Cardiac plate possesses 21–23 spinules. Cardiac ossicle invertedly trapezoidal with corners rounded, 0.8 times as long as wide; anterior margin 1.8 times the length of posterior one. Pterocardiac is of Type-Q_3. Prezygocardiac bar-shaped with pointed inner and outer ends, triangularly expanded at middle of posterior border. Urocardiac helmet-shaped at tip with considerably concave apical border (Fig. 143, *E*). Zygocardiac belongs to Type-R_2 (Fig. 78, *G*). Prepyloric subpentagonal in dorsal aspect, tapers into a large bluntly pointed median tooth in posterior half; each post-lateral margin armed with 4 conical teeth much smaller than the median tooth (Fig. 75, *A* and *G*).

Sexual difference: Besides copulatory organs and second pleopods, the following items supply some cases of sexual dimorphism in this species: (1) rostrum shorter in male than in female, reaching about middle of intermediate joint of antennular peduncles, 0.54–0.59 times the length of carapace in male; extending to or somewhat beyond tip of the peduncle, 0.62–0.72 times the length of carapace in female; (2) eye larger in male than in female, viz., longer diameter of cornea is two-ninths to two-tenths the length of carapace in male, instead of being two-elevenths, (3) antennular flagella much longer in male than in female; inner ramus 0.97–1.31 times the length of carapace in male. 0.56–0.68 times in female, and thickened in two-thirds and suddenly gets filiform in the rest in male, whilst it is thin and simply tapers in female; (4) antennal scale surmounted by about half of third segment of antennular peduncle in male, while it reaches to tip of the peduncle in female; (5) stalk of first pleopod triangularly produced forwards as in that of second pleopod of *Solenocera*, and has its outer anterior border more strongly swollen in male than in female,

Three males, 72.8–78.0 mm long (18.5–20.1 mm in carapace-length), and 15 females, 84.2–107.0 mm long (23.7–31.5 mm in carapace-length) were dealt with herein.

Locality: Heta and Maisaka, Shizuoka Pref.; Kumano-nada, off Owase, Mie Pref. (ca. 370 m).

Distribution: Off Tablus Island (100–115 fathoms); off Zebu (95–100 fathoms), 8° 56′ *S.*, 136° 5′ *E.* (49 fathoms) (BATE); Ganjam coast (45–50 fathoms), *G.* of Martaban (46–67 fathoms), Andamans (55 fathoms), Zebu (ALCOCK); Timor Sea (112 m), near Rotti-Island (216 m), Lobelobi-strait (247 m), North coast of Sumbawa (274 m) (DE MAN); South-east of Shikoku (126 m), Southern Bungo Strait (136 m), South of Kôti (97 m) (YOKOYA); Red Sea and Natal; Dzushi (50–100 m), Yokohama, Tsukura (Sagami Bay) (BALSS); Huzan (fish market), Tyôsen (Yoshida).

Note: The present specimens well agree with the descriptions and figures given by ALCOCK, DE MAN, BALSS, and YOSHIDA, but differ from those rendered by BATE in one point: the longer (inner) antennular flagellum is 0.95–1.33 times the length of its peduncle in male as is the case with DE MAN's specimens (De Man, *op. cit.* p. 80), as long as in female instead of being half the length of the peduncle (BATE, *op. cit.* p. 264).

Remarkably enough, all our specimens are found bearing sigmoid rostrum regardless of sex and size of body as in DE MAN's specimens, and none with horizontally straight rostrum like those of BATE's and ALCOCK's. The rostral spines appear to vary 5 to 7 (mostly 6) in number in addition to an epigastric spine: 5 found in 4, 6 in 9, and 7 in 5 specimens. The ultimate spine is always situated above the frontal margin of the carapace.

Parapenaeus sextuberculatus sp. nov.

(Figs. 7, *F′*; 21, *B*; 28, *D-F*; 47, *R*; 61, *A* and *A′*; 75, *B* and *H*; 78, *H*; 143, *B* and *F*).

The present species strikingly resembles *Parapenaeus fissurus* (BATE), but differs from it, such as:

Rostrum of male reaches to or a little beyond distal end of first segment of antennular peduncle, somewhat arcuate and slightly recurved at tip, with 5 or 6 teeth above in addition to epigastric tooth. Antennular peduncle of male smaller than in female in relative length compared with carapace. Antennular flagella of male subequall in length; inner ramus thickened in proximal half. Maxillulary palp produced into a bluntly pointed tip at disto-lateral angle (Fig. 143, *B*). Third pereiopods not reaching to tip of third maxilliped but extends as far as distal end of propodus. Fifth pereiopod hardly or really reaches to middle of the last joint of third maxilliped.

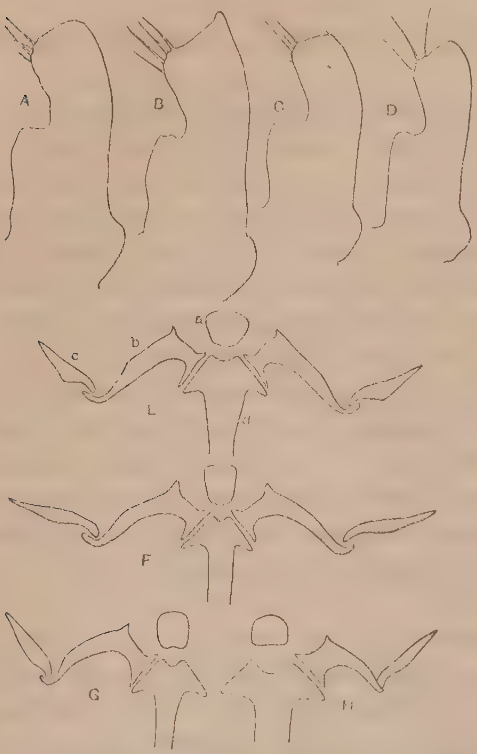

Fig. 143. Maxillulary palp (*A–D*), cardiac (*a*), pterocardiac (*b*), prezygocardiac (*c*) and anterior half of urocardiac (*d*) ossicles (*E–H*). *A* and *E*, *Parapenaeus fissurus*; *B* and *F*, *Parpaenaeus sextuberculatus*, sp. nov.; *C* and *G*, *Parapenaeus lanceolatus* sp. nov.; *D* and *H*, *Parapenaeus investigatoris*. *A–D*, ×20; *E* and *F*, ×10.5; *G* and *H*, ×15; *I*, ×35.

Appendix masculina: upheaval lying on anterior surface of proximal piece broad, with rounded apex; apical surface of distal piece a little longer than wide (Fig. 61, *A* and *A'*).

Petasma: process–*a* broad, with anterior smaller and posterior larger pointed projections at apex; process–*b* equally broad, obtusely pointed; process–*c* with pointed apex curved anteriorly, raised as far as process–*b*; process–*d* absent (Fig. 28, *D–F*).

Thelycum consis of an antero-median, a postero-median, and a pair of antero-lateral as well as postero-lateral bosses on each side: antero-median lying on sternite between fourth pereiopods, invertedly cardiform, with convex ventral surface, the largest of all; posteromedian located at middle of the last thoracic sternite, greatly exceeded by all others; antero-lateral almost at middle, in level, of antero- and postero-medians, pyramidal in shape, the highest of all; postero-lateral laid down on posterior ridge of the last thoracic sternite, somewhat smaller than antero-median one (Fig. 47, *R*).

Cardiac plate has about 26 spinules (Fig. 78, *H*). Cardiac ossicle subrectangular, 1.3 times as long as wide, a little narrowed posteriorly (Fig. 143, *F*). Prepyloric with 4 teeth on each postero-lateral margin as in *P. fissurus*, but the teeth somewhat slenderer than those of the said species (Fig. 75, *B* and *H*).

Holotype: male, 91 mm long (23.3 mm in carapace-length).

Paratype: 3 males, 81–85 mm long (20.6–21.5 mm in carapace-length), and 2 females, 87.5 mm and 96 mm long (23.8 mm and 25.4 mm in carapace-length).

Locality: Heta and Maisaka, Shizuoka Pref. (ca. 330 m).

Parapenaeus lanceolatus sp. nov.

(Figs. 4, *C*; 7, *D′*; 21, *C*; 28, *G-I*; 61, *C* and *C′*; 75, *C*, *I*; 78, *I*; 143, *C*, *G* and 144)

The present species intimately resembles *Parapenaeus fissurus* (Bate) and *Parapenaeus sextuberculatus* sp. nov., but nearer to the former in the features of the rostrum, antenule, antennal scale, maxillulary palp (Fig. 143, *C*), appendix masculina, and cardiac plate (with 21–23 spinules) (Fig. 78, *I*).

Separable from the above-mentioned two by the characters of petasma, viz., process–*a* well-developed, sharply pointed at apex, directed antero-laterally; process–*b* markedly developed, acutely pointed at tip, directed dorso-medially in terminal portion; process–*c* narrowly rounded at apex, produced as far as process–*b*, directed dorso-anteriorly; process–*d* short, dentiform, much smaller than that of *Parapenaeus fissurus*.

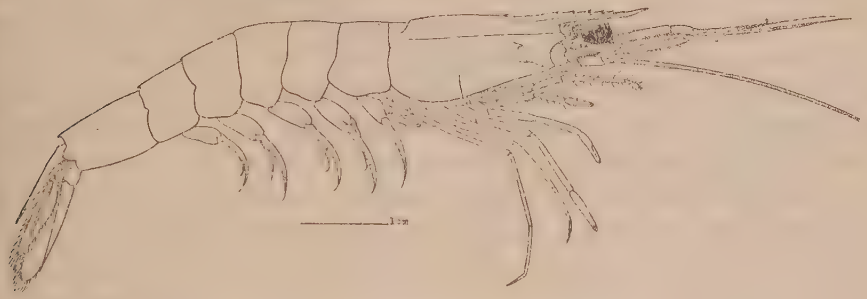

Fig. 144. *Parapenaeus lanceolatus*, sp. nov., male, 67.7 mm long.

Besides these, the protuberance located on anterior surface of proximal piece of appendix masculina and number of the teeth lying on each postero-lateral margin of prepyloric ossicle, and cardiac ossicle appear different from those of the two species under consideration. However, these distinctions are less significant for recognition of the present species. The protuberance of appendix masculina (Fig. 61, *C* and *C′*) and cardiac ossicle are intermediate in feature between those of the two species, the latter subrectangular in the present species, and a little longer than wide with somewhat emarginate posterior edge (Fig. 143, *G*). Prepyloric ossicle provided with five (instead of four) teeth along each postero-lateral margin (Fig. 75, *C* and *I*).

Holotype: male, 67.1 mm long (17 mm in carapace-length).

Paratype: four males, 61–75 mm long (15.5–20.0 mm in carapacial length).

Locality: Heta, Shizuoka Pref.; and Kumano-nada off Owase, Mie Pref. (300–350 m).

Parapenaeus investigatoris ALCOCK and ANDERSON

(Figs. 7, *E'*; 21, *D*; 28, *J–L*; 47, *Q*; 61, *D* and *D'*; 75, *D* and *J*; 78, *J*; 143, *D* and *H*; and 145).

Parapenaeus investigatoris, ALCOCK and ANDERSON 1899, 279; DE MAN, 1911, p. 80.
Parapeneus investigatoris, ALCOCK, 1906, p. 32, pl. 6, fig. 17 and 17 *a–c*.
Peneus (Parapeneus) investigatoris, ALCOCK, 1901, p. 18.
Parapenaeus fissurus, ALCOCK and ANDERSON, 1894, p. 144.

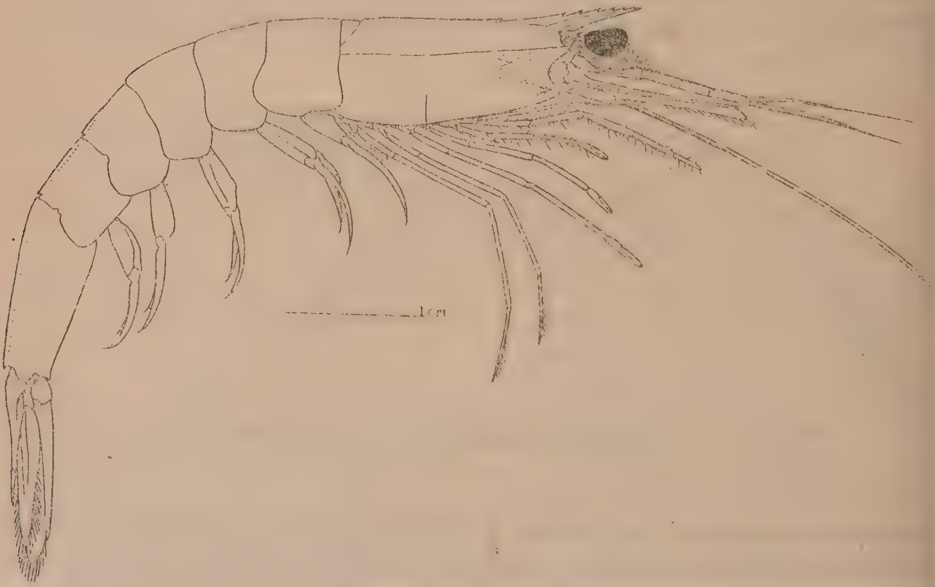

Fig. 145. *Parapenaeus investigatoris* ALCOCK and ANDERSON, male, 63 mm long.

Rostrum styliform, tilted somewhat upward, about 0.4 times the length of carapace. Epigastric tooth set a little anteriorly to one-third of carapace. Hepatic spine lying below epigastric tooth. Abdomen dorsally carinated posterior to middle of fourth segment; each of the carinae has a spinule at posterior extremity, and each tergum of fourth and fifth segments a little incised posteriorly. Sixth pleonic segment with spiniform postero-inferior angles, 2.5 times as long as wide, 0.8 times the length of carapaca.

Eye moderate in size, about two-ninths the length of carapace in longer diameter of cornea. Prosartema extends as far as eye. Stylocerite attains half-way of basal segment of antennular peduncle. Antennular peduncle as long as carapace in male, about 0.7 times as long as carapace in female; first article with a spinule at disto-lateral angle; second twice the length of third article in male, 2.3 times the length of the third in female. Antennular flagella, in male, subequal in length, somewhat shorter than carapace; upper ramus thickend in proximal one-third, and so the lower in basal two-thirds. Basicerite has a spine directed antero-ventrally on distal outer edge. Scaphocerite reaches to tip of antennular peduncle in male, surpassing tip of the peduncle by about one-sixth in female, rather narrow, ca. 3.6 times as long as wide measured near base, distally narrows by half, with a prominent disto-lateral spine which is slightly surmounting apex of lamellar. Carpocerite extends as far as eye.

Mandible: molar process with flattish masticatory surface which is subrectangular in outline, with inner masticatory edge produced and sharper than the outer; incisor process with two acute teeth in distal half; palp similar to that of preceding species of *Parapenaeus*, but less excavated at disto-lateral angle of second joint (Fig. 7, *E′*). Maxillulary palp (Fig. 143, *D*), and anterior two maxillipeds closely resemble those of *P. fissurus* in general configuration. Third maxilliped pediform, hairy, reaches to or slightly beyond distal end of second segment of antennular peduncle in male, but it reaches to tip of the peduncle in female, proportions in length to dactylus: ischium 2, merus and carpus 1.7, propodus 1.5.

First pereiopod attains far end of carpocerite, with basial and ischial spines. Second reaching anterior end of basal segment of antennular peduncle. Third reaches about middle of intermediate joint of antennular peduncle, proportion in length to movable finger: ischium 1.5, merus 3, carpus 3.3, palm 0.7. Fourth extends as far as third leg, with thickly set hairs along anterior surface distally to middle of propodus. Fifth stretches to far end of second segment of antennular peduncle, bearing a thicket of hairs as in fourth limb, proportions in length to the last joint; ischium 2.3, merus and carpus 5, propodus 3.

Appendix masculina closely related to that of *P. fissurus* with a rather narrow protuberance on anterior surface of proximal piece, but apical surface of distal piece a little longer than wide (Fig. 61, *D* and *D′*).

Petasma considerably deviating in feature from that of other three *Parapenaeus* given alread: process–*a* rather vestigial, directed forward, with broadly rounded disto-ventral angle and bluntly pointed disto-dorsal one; process–*b* less developed, with truncate apex, directed disto-dorsally; process-*c* hardly elevated; process-*d* absent; process-*e* thin, twice the width (Fig. 28, *J*–*L*).

Thelycum well agrees with ALCOCK's description and figure (Fig. 47, *Q*).

Cardiac plate has 35–37 equidistant spinules alined longitudinally along its entire length, last two of which are much larger than others (Fig. 78, *J*). Cardiac ossicle subrectangular in outline, more or less wider than long, with convex anterior margin. Pterocardiac, and urocardiac ossicles similar to, but somewhat wider than, those of all other *Parapenaeus* (Fig. 143, *H*). Zygocardiac provided at anterodorsal angle with a large tooth which is followed 5 small conical teeth arranged longitudinally in a row and becomes gradually smaller backward, and furnished with many rather thickly set spinules near ventral edge in posterior half (Fig. 78, *J*). Prepyloric possesses 5 acute teeth on each postero-lateral edge, besides a median tooth which is depressed, much larger than those lying on postero-lateral edge (Fig. 75, *D* and *J*).

The following 3 specimens were examined: two males, 62 mm and 63 mm long (14.0 mm and 14.9 mm in carapace-length); and a female, 73 mm long (18 mm in carapace-length), in which antennular and antennal flagella, and posterior three pairs of pereiopods are mutilated.

Locality: Off Maisaka, Shizuoka Pref. (ca. 300 m).

Distribution: Off Pulicate; G. of Manar; Andaman Sea (N. E. of North I.) (133–419 fathoms) (ALCOCK), Near Kei Islands (310 m) (DE MAN).

Note: The specimens on hand well agree with descriptions and illustrations given by previous investigators.

The present species is far remote from other three *Parapenaeus* afore mentioned in the following points: (1) carination of carapace and abdomen, (2) branchiostegal spine, (3) sixth pleonic somite, (4) petasma, (5) thelycum, and (6) cardiac plate.

Genus *Metapenaeopsis* BOUVIER (emend)

Metapenaeopsis, BOUVIER, 1905 *a*.
Penaeopsis, DE MAN, 1911 (part), pp. 53–55 and p. 61; BALSS, 1914 (part), pp. 6–7; 1925 (part), p. 228; KEMP, 1915, (part), p. 321; SCHMITT, 1926 (part), pp. 319–323; BURKENROAD, 1934 (part), pp. 4–12.
Leptopenaeus, KISHINOUYE, 1929, p. 282.
Ceratopenaeus, KISHINOUYE, 1929, p. 282.
Erythropenaeus, KISHINOUYE, 1929, p. 283.
Metapeneus, ALCOCK, 1906 (part) p. 16.

Rostrum well-developed, with teeth above. Cervical, hepatic, and orbito-antennal grooves ill-defined. Antennal, branchiostegal or pterygos-

omian, and hepatic spines present. Abdomen dorsally carinated. Telson
as a pair of fixed dorso-lateral spines posterior to a series of movable
nes. Stylocerite extending as far as basal antennular segment. Anten-
ular peduncle with a mostly vestigial spine on distal ventro-median
order of first antennular segment. Maxillulary palp unsegmented.
hird maxilliped pediform, without any sexual modification. Basial
pine present on third maxilliped, first and second pereiopods, lacking
n the third leg. Exopodites appear on all thoracic appendages. Appen-
ix masculina is of Type–O_7. Petasma jointed, asymmetrical. Thelycum
urnished with a conspicuous plate on sternite between fourth pereiopods,
nd usually has a transverse ridge across the last thoracic sternite.
terocardiac ossicle belongs to Type–Q_1, and zygocardiac Type–R_5.

A pleurobranchia and an arthrobranchia present on seventh thoracic
omite, and an anterior vestigial arthrobranchia of the somite mostly
resent but sometimes absent (as in *M. lamellatus*). A mastigobranchia
et on anterior three pereiopods. Typical branchial arrangement is
iven in Table 6, *G*.

The present genus was established for reception of *Metapenaeopsis*
ubescens by BOUVIER (1905 *a*), but was made by BURKENROAD (1934 *b*,
p. 4–8) a subgenus of the genus *Penaeopsis*, involving the whole
enaeids with asymmetrical petasma. Evidently, however, such Penaeids
re decidedly distinguished from those of *Penaeopsis* and all other gene-
a of the family Penaeidae by many features which are of fully generic
gnificance, viz., copulatory organs, appendix masculina, zygocardiac
ssicle, etc.

KISHINOUYE (1929) subdivided the group "asymmetrica" into
hree: *Leptopenaeus*, *Ceratopenaeus*, and *Erythropenaeus*, mostly basing
n the condition of the copulatory organs. But his classification appears
o the writer not tenable, inasmuch as it is revealed after close exami-
ation that the demarkations given by him are very obscure because
oints of distinction as pointed out by him are interchangeable within
ne "asymmetrica". He mentions in the definition for the *Leptopenaeus*
anterior margin of the petasma is entire; not divided", and for
eratopenaeus "right lobe of petasma broader than the left". However,
oth the disto-ventral projections of the petasma of *Metapenaeopsis*
miger (WOOD-MASON), which is, according to KISHINOUYE, referable to
eptopenaeus, bear many apical appendages (Fig. 35) which show ap-
arently a rudimentary condition of those of *Metapenaeopsis acclivis* and
s congeners (Fig. 18). Also the right lobe of the petasma of *Meta-*
enaeopsis (=*Ceratopenaeus*) *lamellatus* (DE HAAN), appears shorter than
ne other as in those of *M.* (=*Erythropenaeus*) *acclivis*, and its related
orms, but never broader than the other (Fig. 34). The thelycum of
ne penaeids in question is also too variable to assort them to such

genera as coined by KISHINOUYE.

For instance, the organ of *Penacopsis borradaili* of DE MAN(1) ar *Parapenaeus kishinouyei* of RATHBUN(2) link in feature the genera erec ed by KISHINOUYE.

The present genus has an intimate ralation to *Penaeopsis* (in se restricts) by having carapace with a branchiostegal spine, telson wi fixed dorso-lateral spines, antennular peduncle having the "parapenae spine", unsegmented maxillulary palp, and exopodites on all pereiopoc branchiae except anterior vestigial arthrobranchia of seventh thorac somite, but easily separable from the latter on the basis of the follo ing items: third maxilliped and first pereiopod have a basial spin petasma jointed and asymmetrical, appendix masculina is of Type-(pterocardiac ossicle Type-Q_1, and zygocardiac Type-R_5. Also it is al ed to *Metapenaeus*, especially in the branchial arrangement, but great differentiated from the latter in many significant features, namely, ca pace without sharply defined cervical and hepatic carinae, but with branchiostegal or pterygostomian spine, telson carrying a pair of fix spines; maxillulary palp unsegmented; fifth pereiopods with exopodi basial spine present on third maxilliped, absent on third legs; petas jointed, asymmetrical; thelycum without a pair of lateral elevations the last thoracic sternite; appendix masculina being of Type-O_7; zygocardiac of Type-R_5.

It is worth noting that the characters given below are comn throughout all the examined species besides those enumerated for generic distinctions.

Epigastric spine present. Second abdominal segment with an defined dorso-median carina, and the sixth with a minute spine direc posteriorly at each postero-inferior angle. Telson with a rather shall median groove on dorsal surface, and three pairs of movable do lateral spines preceding to a pair of fixed ones. Eye armed with depressed acute scale directed forward on distodorsal edge of basal jo Prosartema slender, reaching to or slightly beyond far end of first ant nular segment. Basal antennular segment in possession of considera developed upstanding plate-like protuberance on disto-dorsal border, a sharp disto-lateral spine. Antennal scale with a disto-lateral s extending as far as apex of lamella. Mandible carrying an incisor cess which has a notch near anterior end of cutting rim. Maxilla b of Type-G_1. First cheliped bearing an ischial spine.

In passing it may be mentioned that the body-form of deep inhabitants, viz., *M. coniger* (WOOD-MASON) and its allied forms is, a whole, much slenderer than that of littoral forms. Hand in h ith this character, the rostrum, sixth pleonic somite, antennular pedun-es, and antennal scales are markedly slender in the bathybic species. n addition to these, the following facts seem to the writer to be pecu-ar to these Penaeids. The distal ventro-median spine or "Parapenaeid pine" of the basal antennular peduncle exists in a well developed con-tion as in *Penaeopsis rectactus* (BATE). The zygocardiac ossicle is rovided with merely two large conical teeth, although the ossicle of the ttoral forms dealt with have accessory teeth without exception (Figs.) and 81).

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(1) DE MAN, 1911, pp. 73-75, pl. 8, fig. 24 (1913).

(2) BOONE, 1930, pp. 108-110, text-fig. 3, pl. 33.

Besides the eight species dealt with under this genus the three, *arapenaeus mogiensis* RATHBUN, *Metapenaeus coniger* var. *andamanen-s* WOOD-MASON and the spacies reported as *Metapenaeus barbatus* (DE AAN) from Formosa by MAKI and TSUCHIYA(1) have been known to be ferable to the present genus, although unfortunately they are not presented in the material at the author's dispoal. The following Indo-acific species are also probably included in this genus: *Penaeopsis ovae-guineae* (HASWELL)(2) (=*Metapeneus stridulans* (ALCOCK),(3) *Pena-psis sibogae* (DE MAN),(4) *Penaeopsis distinctus* (DE MAN),(5) *Penaeopsis uinquedentatus* (DE MAN),(6) and *Penaeopsis borradailei* (DE MAN), (*op.* .).

Key to the Japanese species of the genus *Metapenaeopsis*

A₁ Sixth pleonic somite much less than twice as long as wide measured near posterior end; antennular peduncle has a vestigial spine on distal ventro-median border of basal segment; longer antennular flagellum much less than half the length of carapace; thelycum furnished on sternite between fourth pereiopods with a conspicuous plate elevated anteroventrally and not extending backward

  B₁ Stridulating-organ present

    C₁ Dorso-median carina of third abdominal segment with flattish or hardly grooved surface; antennular flagella ca. a third the length of carapace; petasma has inner intermediate strip surmounting the outer one; stridulating-organ consists of 13–25 ridges

      D₁ Rostrum reaches to or a little beyond tip of antennular peduncle; stridulating-organ made up of 13–25 (mostly 18–22) ridges; left disto-ventral projection of petasma with less developed apical appendages; anterior plate of thelycum subrectangular, 1.5 times as wide as long, much larger than coxal plate of fourth pereiopod ....*M. barbatus* (DE HAAN) (=P. *akayebi* RATHBUN).

) MAKI and TSUCHIYA, 1923, pp. 35–36, pl. 3, fig. 3.

) SCHMITT, 1926, pp. 341–343, pls. 61, fig. 2, and 68, fig. 2.

) ALCOCK, 1906, pp. 27–28, pl. 5, fig. 14.

) DE MAN, 1911, pp. 63–64, pl. 6, fig. 18 (1913).

) „ „ 1911, pp. 69–70, pl. 7, fig. 21 (1913).

) „ „ 1911, pp. 71–73, pl. 7, fig. 23 (1913).

D_2 Rostrum reaching to distal end of first segment of antennular peduncle stridulating-organ made up of 13-18 ridges; left disto-ventral projectio of petasma with remarkably developed apical appendages; anterior plat of thelycum somewhat flabelliform, as long as wide, as large as coxa plate of fourth pereiopod ....*M. acclivis* (RATHBUN)

C_2 Dorso-median carina of third abdominal segment with a clearly defined median groove; antennular flagella about half the length of carapace; petasm has inner intermediate strip much exceeded by the outer; anterior plate o thelycum flabelliform, as long as wide, as large as coxal plate of fourt pereiopod; stridulating-organ consists of 28-35 ridges ....*M. durus* sp. nov

B_2 Stridulating organ absent

E_1 Epigastric tooth inserted at about a quarter of carapace; hepatic tooth lyin below the epigastric; dorso-median carina of third pleonic segment as full developed as that of fourth one; antennal scale much more than twice a long as wide measured at base; anterior arthrobranchia present on sevent thoracic somite; thelycum has a minute median spine on distal border o transverse plate lying on sternite between fourth pereiopods

F_1 Thelycum has no projections just behind transverse plate lying on sternit between fourth pereiopods, but has a large acute spine at each outer en of transverse ridge placed on the last thoracic sternite

G_1 Median triangular process of posterior ridge of the last thorac sternite of female strikingly large ....*M. dalei* (RATHBUN

G_2 Median pointed process of posterior ridge of the last thoracic sterni of female rudimentary ....*M. incomptus* sp. no

F_2 Thelycum has a pair of conspicuous projections just behind transver plate lying on sternite between fourth pereiopods, and four protuberan on anterior margin of transverse ridge placed on sternite of the la thoracic somite ....*M. mogiensis* (RATHBUN

E_2 Epigastric tooth set a little posterior to middle of carapace; hepatic too located much anterior to epigastric tooth; dorso-median carina of thi pleonic somite much more prominent than that of fourth somite; anten scale twice as long as wide measured at base; anterior arthrobranchia abse on seventh thoracic somite; thelycum has a salient acicular appendage middle of anterior border of transverse plate lying on sternite between fourt pereiopods, and a pair of tumid median protrusions as well as a pair auriculate lateral protrusions on anterior margin of transverse ridge lying the last thoracic sternite; petasma given off a styliform autgrowth at ap of right disto-ventral projection, and has two or three similar ones at ap of left disto-ventral projection ....*M. lamellatus* (DE HAAN

A_2 Sixth pleonic somite much more than twice as long as wide measured near poster end; anntennular peduncle bears a well developed acicular spine on distal vent median border of basal segment; longer antennular flagellum about half the leng of carapace; thelycum provided on sternite between fourth pereiopods with a la tumid plate not raised antero-ventrally, but remarkably extending backward

H_1 Thelycum has a large tongue-like protrusion on posterior border of anterior pl lying between fourth pereiopods

I_1 The tongue-like protrusion double convex on posterior margin, rounded posterolateral angles ....*M. coniger* (WOOD-MASON

I_2 The tongue-like protrusion emarginated on posterior margin, angulated posterolateral angles ....*P. coniger andamanensis* (WOO-MASON

H_2 Thelycum bears a pointed protrusion on posterior border of anteri plate lying between fourth pereiopods

J_1 Abdomen dorsally carinated posterior to first segment; postero-medi protrusion of anterior plate of thelycum not reaching to posterior ridge of the thoracic sternite ....*M. latus* sp. nov.

J2 Abdomen dorsally carinated posterior to second segment; postero-median protrusion of anterior plate of thelycum almost reaching to posterior ridge of the last thoracic sternite ....*M. kyushuensis* (YOKOYA)

Metapenaeopsis barbatus (DE HAAN)

(Figs. 1, *D*; 4, *B*; 8, *B*; 18, *D-F*; 22, *M*; 42, *A-N*; 46, *B*; 50, *A-D*; 64, *A*; 68, *A-F*; 76, *C* and *H*; 80, *J*; 146; 147; *A-D*; 148, *A* and *I*.)

Penaeopsis barbatus, DE MAN, 1911, p. 88; HIRUMA, 1925, pp. 424-425, fig. 6.
Parapenaeus akayebi, RATHBUN, 1902, p. 39.
Penaeus (*Metapenaeus*) *akayebi*, DE MAN, 1907, pp. 433-434, pl. 33, fig. 54.
Metapenaeus akayebi, URITA; 1921, p. 215.
Metapenaeus akayebi, MAKI and TSUCHIYA, 1923, pp. 33-35, pl. 1, fig. 4.
Erythropenaeus akayebi, KISHINOUYE, 1929, p. 283 (except Fig. of petasma on p. 281 for *Erythrop. akayebi*); YOKOYA, 1930, pp. 526-527; 1933, p. 8.
Penaeus veltinus KISHINOUYE, 1900, p. 26-27, pl. 6, fig. 2 and pl. 7, fig. 11 (except petasma).
Penaeopsis acclivis, OSADA, TANIZAKI and NAKAZAWA, 1936, pp. 7-8, pl. 4 (Lower, left).
Not: *Penaeopsis barbatus*, PARISI, 1919, pp. 61-62, pl. 5, fig. 3.
Not: *Metapeneus barbatus*, MAKI and TSUCHIYA, 1923, pp. 35-36, pl. 3, fig. 3.

Rostrum straight or slightly uptilted in distal two-fifths, reaches to or a little beyond tip of antennular peduncle, armed above with 6 or 7 teeth except epigastric tooth. Epigastric, supra-orbital, antennal, branchiostegal and hepatic spines present, subequal in size except supra-orbital spine which is smallest of all. Epigastric stands at a fourth of carapace, hepatic below epigastric and more or less inferior in horizontal level to antennal spine, branchiostegal arises from anterior margin of carapace. Pleon dorsally carinated posterior to first segment: the carina of third segment the most prominent, flattish or hardly grooved longitudinally on upper surface, and becomes gradually wider in posterior two-thirds, each one of fifth and sixth segments ends in a pointed spinule; terga of fourth and fifth segments considerably incised at middle of posterior edge, with an acute projection on each side of the incision. Telson well surmounts apex of outer uropods, with three pairs of movable and a pair of immovable dorso-lateral spines behind these movable ines; the first pair of movable placed at middle and the last pair at hree-fourths; the immovable as large as movable of the first pair, and a little less than half the length of intermediate ones (Fig. 4, *B*).

Eye has a depressed pointed scale directed forwards on upper anterior border of peduncular joint. Basicerite has a spine directed anteroventrally on distal outer edge. Scaphocerite reaching tip of antennular eduncle, about thrice as long as wide measured in the widest region, gradually narrows anteriorly by about a third, with a stout disto-lateral spine which extends slightly beyond apex of lamella. Carpocerite extends below about middle of cornea, twice as long as wide.

Mandible: molar process almost flat on masticatory surface which is ovoid in outline. Incisor one with a notch near anterior angle. Palp attains inner end of third antennal segment, distal segment broad with rounded apex and strongly convex outer margin, ca. 1.3 times the width (Fig. 8, *B*). Maxillulary palp unsegmented, rather narrowly rounded at tip, with three prominent protrusions, two on anterior and one on posterior margins (Fig. 148, *A*). Maxilla is of Type-G_1. First maxilliped with bluntly pointed lamellar exopodite; endopodite five-jointed, proportions in length to the last joint: first 2.5, second 0.7 third 1, fourth 1.9; first joint has several large setae near middle inner edge. Second seven-jointed, meropodite laminar on inner hal somewhat more than twice as long as wide, 1.7 times the length dactylus. Third reaches to or beyond distal end of second segment antennular stalk, relative lengths to dactylus: ischium and carpus 1. merus and propodus 1.3; exopodite attains far end of merus.

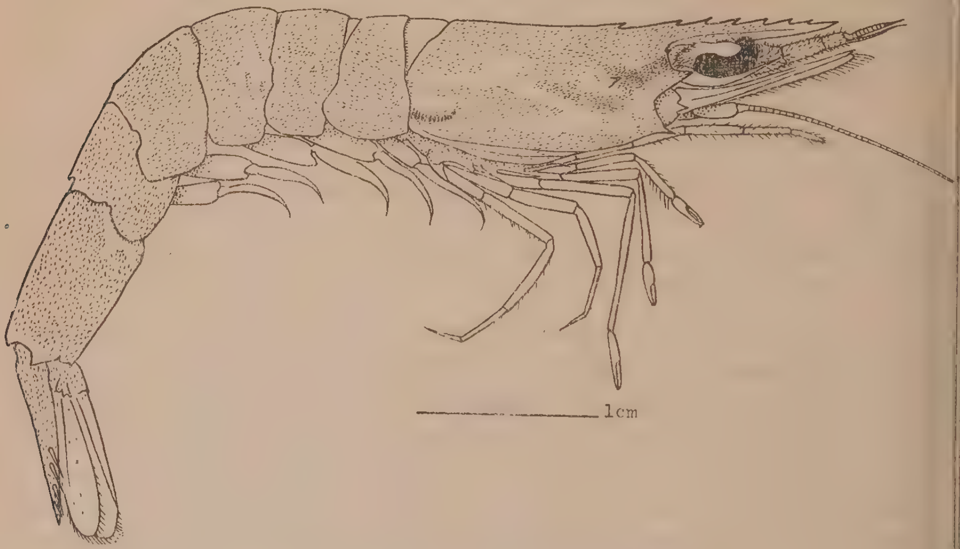

Fig. 146. *Metapenaeopsis barbatus* (DE HAAN), male, 55 mm long.

First pereiopod reaches beyond distal end of basicerite by half chela. Second surpassing carpocerite by half of chela. Third usuall extending to far end of second article of antennular peduncle, sometime reaching more or less beyond tip of the peduncle, proportions in lengt to movable finger: ischium 1.3–1.5, merus 3.0–3.8, carpus 4.7–5. palm 0.9–1.3. Fourth stretching as far as first leg; coxal plate wel developed, projected postero-medially with rounded apex, reaching about middle of the last thoracic sternite, about a half smaller than anterior transverse plate of thelycum (Fig. 46, *B*). Fifth reaches to or surpassing distal end of carpocerite by about half of dactylus, proportions in length to the last joint: ischium 1.3–1.5, merus 2.5–3.0, carpus 2.2–2.8, propodus 1.5–2.0.

Appendix masculina(a) is of Type–O_7 (Fig. 64, *A* and *A'*).

Petasma(a) belongs to Type–M_{11}; right disto-ventral projection carries an apical protuberance; tip with three or four spinules; left disto-ventral projection considerably thickened, suboval in cross-section (Fig. 18, F, *a*), and has 7–12 apical outgrowths, most of which are divided into two pointed spinous appendages at apex, much larger and longer than right disto-ventral projection; inner intermediate strip broad, exceeded by spical protuberance of right distoventral projection, much larger than outer intermediate strip (Fig. 18, *D* and *E*).

Thelycum(b) is of Type–N_4; a transverse plate lying on sternite between penult pereiopods, about 1.6 times as wide as long, with almost straight apical margin minutely pointed at middle and rounded at distolateral angles, directed antero-ventrally; a low ridge present behind the transverse plate on each side, directed anteromedially, hiden by coxal plate of fourth pereiopod; a transverse ridge, which runs across about middle of the last thoracic sternite, somewhat w-shaped with median part anteriorly convex and each lateral part semicircularly curved inward reaching near postero-median base of fourth pereiopod; posterior edge of the last thoracic sternite bears an median and a pair of lateral protuberances, all of which are directed antero-ventrally, median protuberance less prominent, obtusely pointed; lateral ones rather prominent, somewhat lamellar, with rounded apex reaching posterior margin of the w-shaped ridge (Fig. 46, *B*).

Cardiac plate in possession of a longitudidal row of 25–28 equidistant spinules running the entire length of inner surface (Fig. 80, *J*). Cardiac ossicle subrectangular in outline with corners rounded, a little longer than wide (Fig. 148, *I*, *a*). Pterocardiac bar-shaped, laterally narrowed into a point, slightly curved forward in outer subterminal portion, somewhat produced backward at postero-median angle, with median margin passing almost parallel to antero-lateral edge of urocardiac ossicle (Fig. 148, *I*, *b*). Prezygocardiac assumes the outline of a hornflute with narrowly rounded inner end and triangularly expanded outer half (Fig. 148, *I*, *c*). Urocardiac broad, twice as long as wide, pointed with an obtuse angle at anterior end, and has a large pointed projection directed sidewise near anterior end (Figs. 76, *C* and *H*, and 148, *I*, *d*). Zygocardiac furnished with two large teeth on anterior edge, and another small tooth behind the upper large one (Fig. 80, *J*). Prepyloric with about 17 rather slender sharply pointed teeth along posterior margin, which are subequal in size except first two or three smaller ones of either side (Fig. 76, *C* and *H*).

(a) Metamorphoses of appendix masculina (Fig. 68, *A*–*F*) and petasma (Fig. 42, *A*–*N*) are given already in general part of this paper.

(b) Metamorphosis of thelycum (Fig. 50, *A*–*D*) is given already in general part of this paper.

The description given above is based on moderate sized specimens, 75–80 mm long (17–20 mm in carapace-length). Examined 32 males, 37.2–75.7 mm long (8.5–17.6 mm in carapace-length), and 63 females, 35.2–91.0 mm long (7.9–22.0 mm in carapace-length), collected from Tateyama, Chiba Pref., Miya, Aichi Pref., Ushimado, Okayama Pref., Tomo, Hiroshima Pref., Shimonoseki (fish market), Yamaguchi Pref., Nagasaki, and Sashiki, Kumamoto Pref. Besides these, 17 males, 43.6–78.0 mm long (10.9–18.2 mm in carapace-length), and 16 females, 55.4–91.1 mm long (13.8–23.5 mm in carapace-length secured off South coast of Borneo, on Dec. 9, 1932 by training ship "the Hakuyo-Maru".

Distribution: Japan (DE HAAN); Inland Sea, Bay of Ise (KISHINOUYE); Inland Sea of Japan (DE MAN); Mutsu Bay to Kyûsyû (YOKOYA) Kagoshima-Wan (URITA); Ushimado, Tomo (Inland Sea) (HIRUMA) Sashiki (Kumamoto Pref.) (OSADA, TANIZAKI and NAKAZAWA); Taka (Formosa) (MAKI and TSUCHIYA).

Note: The rostrum varies in shape in larger specimens as give elsewhere, but it is always straight in smaller ones than at least 60 m long (15 mm in carapace-length) irrespective of sex. Again, the proportional length changes with age, namely, it is relatively shorter in specimens smaller than about 55 mm in length (13 mm in carapace-length and usually reaching to distal end of the second antennular segmen The spines set on the upper border are 6 or 7 in number except th epigastric spine. Of 96 Japanese specimens, 50 have 6, 46 have 7; where as of 33 Bornean forms, 11 have 6, and 22 have 7.

The single type specimen of *Penaeus barbatus* DE HAAN was re-examined by DE MAN (1911, p. 88) in a dried condition and found having a pair of dorso-lateral subcarinae in the fourth abdominal segmen He says: "perhaps these subcarinae are a product of the desiccation But these are found to exist in both the Japanese and Bornean specimens without exception.

The proportion of longer diameter of the cornea to the carapace length becomes gradully smaller with advance of growth. It is abou 0.4, 0.33 and 0.3 in specimens about 35 mm long (8 mm in carapace length), 60 mm long (14 mm), and 80 mm long (20 mm) respectively.

The trend of changes of the relative length, as referred to carapac of rostrum linearly ascends in smaller specimens than about 75 mm lon

17.5 mm in carapace-length), but turns almost horizontally in larger ones han that given above (Fig. 147, *A*). But the trends are simply linear or those of the sixth abdominal segment and telson. It may be noticed hat all such relative lengths in male seems to be a little larger than hose in female in case larger than about 65 mm long (14.5 mm in arapace-length). These equally hold true for both Japanese and Bornean pecimens (Fig. 147, *B* and *C*).

Regarding the sixth pleonic somite, ratio of the length to the width neasured near the posterior end varies 1.89–2.30 (mostly 1.95–2.15) and .85–2.15 in the Japanese and Bornean materials respectively, although here is tendency slightly decreasing with increase of the carapace-ength (Fig. 147, *D*).

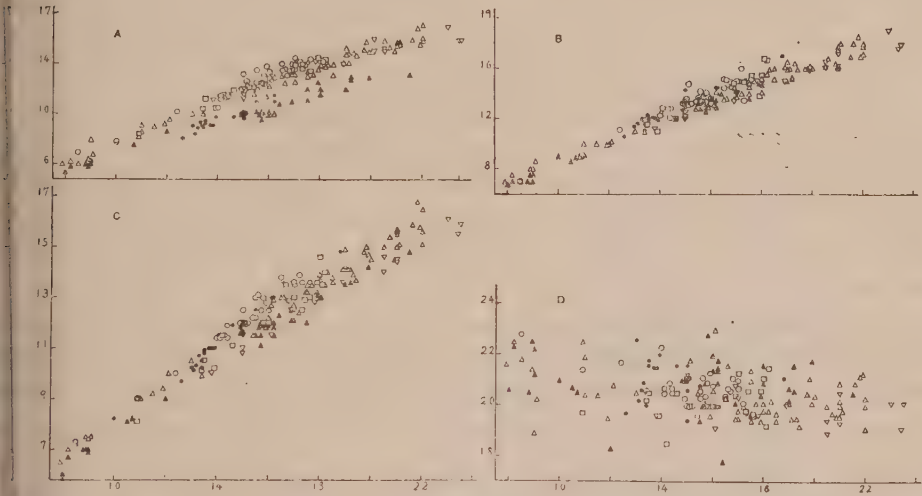

Fig. 147. Dimensions (in mm) in relation to carapace-length (*A*-*C*) and proportions of length of sixth pleonic somite to the width measured near posterior end in relation to carapace-length (*D*). *A*, rostrum; *B*, telson; *C*. sixth abdominal segment. Soft circles and triangles, Japanese specimens of *M. barbatus.* Soft squares and inverted triangles, Bornean specimens of *M. barbatus.* Solid marks, *M. acclivis.* Circles and squares, male. Triangles, female.

The number of the ridges forming the stridulating-organs is subject considerable variation. It ranges 18–25 (mostly 20–23) in the Japaese and 13–23 (mostly 18–20) in the Bornean specimens irrespective of ex and even of body-size.

The Bornean specimens show no differences from the Japanese ones ot only as mentioned above but also in the characters, which were tilized by De Man (1907, p. 434; 1911, p. 69) for discrimination of the resent species from the closely related species, *Penaeopsis stridulans*

(WOOD-MASON), inhabiting East Indian Archipelago and Indian Ocean, viz., (1) the number of ridges forming stridulating-organ; (2) the condi tion of the dorso-median carina of the second pleonic segment; and (3 the shape as well as the proportion of length to width measured near posterior end of sixth pleonic segment. Thus they are referable with certainty to the present species.

All the specimens on hand are not at all fully typical with D HAAN's brief description and illustration differing in possession of less upcurved rostrum, slenderer sixth abdominal somite, much shorter anten nular flagella, scaphocerite not surpassing tip of antennular peduncle and bispinose first pereiopods. But they well agree with DE MAN's (1911, p. 88) description based on DE HAAN's type specimen, 12 mm in carapace-length. Besides, they are well in accordance with the descrip tions and figures of *Parapenaeus akayebi* RATHBUN (1902) and *Penaeus* (*Metapenaeus*) *akayebi* DE MAN (1907). Therefore our specimens may be referred to *Penaeus barbatus* DE HAAN.

KISHINOUYE's account for his *Penaeus velutinus* (=*P. barbatus* differs from the specimens at the authors disposal in the respects give in the following lines. The fourth abdominal segment are represente in his Pl. 6, fig. 2 lacking the pointed projections which should be pr sent on each side of posterior margin of the tergum. The petasm given in his Pl. 7, fig. 11, is greatly different from ours. It is apparentl not that of present species, but that of *Metapenaeopsis durus* sp. nov which will be dealt with later on, since the conditions of the spino apical appendages of the left disto-ventral projection are much mo pronounced and the outer intermediate strip surmounts the tip of th inner intermediate one.

Penaeopsis acclivis of OSADA, TANIZAKI and NAKAZAWA was cha acterized by rostrum reaching to tip of antennular peduncle. It follow therefore, that theirs should be identified with *Metapenaeopsis barbat* (DE HAAN). The present species is very similar to, but quite differe from, *Penaeus velutinus* of DANA (1852, p. 604, pl. 40, fig. 4) and th same of BATE (1888, pp. 253–257, pl. 33, fig. 1). It differs from the fo mer in possession of the annexed characteristics: (1) rostrum not til upwards, reaching to tip of antennular peduncle (2) hepatic spine lo ted below hepatic spine, (3) dorso-lateral spine of telson set in posteri half, (4) third maxilliped not extending to tip of scaphocerite, and second pereiopod much shorter than the third. It is also distinct fro the latter in having hepatic spine below epigastric tooth, telson wi armatures in distal half instead of bearing distal one-third, and antenn scale reaching tip of antennular peduncle (exceeded by the peduncle *P. velutinus* of BATE).

Metapenaeus barbatus of MAKI and TSUCHIYA (1923) from Formos is not identical with the present species at least in having the following peculiarities:—third pereiopods reaching tip of antennal scale; and coxal plates of fourth pereiopods of female absent.

Metapenaeopsis barbatus (De Haan) is a closely allied species to *Penaeopsis stridulans* (Wood-Mason) (Alcock, 1905, p. 526; and 1906, p. 27, pl. 5, fig. 14). However, it is, according to De Man (1907, p. 434; and 1911, p. 69), separable from the species under consideration in having larger number of ridges forming the stridulating-organ (usually 5, occasionally 12 in *P. stridulans*), sulcate dorsomedian carina of second pleonic somite, and less slenderer sixth pleonic one.

Metapenaeopsis acclivis (Rathbun)

(Figs. 1, *M*; 8, *C*; 18, *A–C*; 22, *N*; 43, *A–J*; 46, *C*; 50, *E* and *F*; 64, *B* and *B′*; 76, *D* and *I*; 80, *K*; 147, *A–D*; 148, *B*)

Parapenaeus acclivis, Rathbun, 1902, p. 41, figs. 13 and 14.

Penaeus (*Metapenaeus*) *acclivis*, De Man, 1907, pp. 434–445, pl. 33, fig. 55.

Erythropenaeus acclivis, Kishinouye, 1929, fig. of petasma for *Erythrop. akayebi* on p. 281; Yokoya, 1933, p. 8.

Penacopsis akayebi, Osada Tanizaki and Nakazawa, 1936, p. 7, pl. 4 (upper, right); Yoshida, 1941, p. 13.

Metapenaeus acclivis, Urita, 1921, p. 251.

Penaeopsis barbatus, Parisi, 1919, pp. 61–62, pl. 5, fig. 3.

This form is very similar to *Metapenaeopsis barbatus* (De Haan), with which it was confounded by Balss (1914, p. 8) and Parisi (*op. cit.*), but apparently separable from the latter by the following characteristics.

Rostrum reaches to anterior end of intermediate joint of antennular peduncle; relative length, in relation to carapace, smaller than that of *M. barbatus* (Fig. 147, *A*).

Stridulating-organ composed of 13–18 ridges.

Dorso-lateral subcarinae of fourth abdominal segment less defined than those of *M. barbatus*.

Coxal plates of fourth pereiopods of female as large as, or a little larger than, anterior plate of thelycum (Fig. 46, *C*).

Petasma: right disto-ventral projection thin, arc-shaped in cross-section (Fig. 18, *C*, *a*), with several spinous apical appendages, one or two of which are bifid or trifid; left disto-ventral projection fringed on apex with many pointed appendages which are more developed than those of *M. barbatus*; outer intermediate strip relatively larger than that of the species in question (Fig. 18, *A–C*).

Thelycum: a transverse plate laid down on sternite between fourth pereiopods somewhat flabelliform, as long as wide measured near apex, distally becomes about twice wider, much narrower than that of *M.*

barbatus; a pair of bosses lying behind the transverse plate not recognizable (Fig. 46, *C*).

Cardiac plate with about 23 equidistant spinules alined along its entire length. Zygocardiac has two large teeth as in *M. barbatus*, but the upper tooth followed by about four accessory ones (Fig. 80, *K*).

A lot of specimens, 24 males, 42.1–81.5 mm long (10.0–18.8 mm in carapace-length) and 32 females, 34.0–85.0 mm long (8.0–21.5 mm in carapace-length) were examined.

Locality: Tateyama, Chiba Pref; Miya, Aichi Pref.; Ushimado, Okayama Pref.; Tomo, Hiroshima Pref.; Simonoseki (fish market), Yamaguchi Pref.

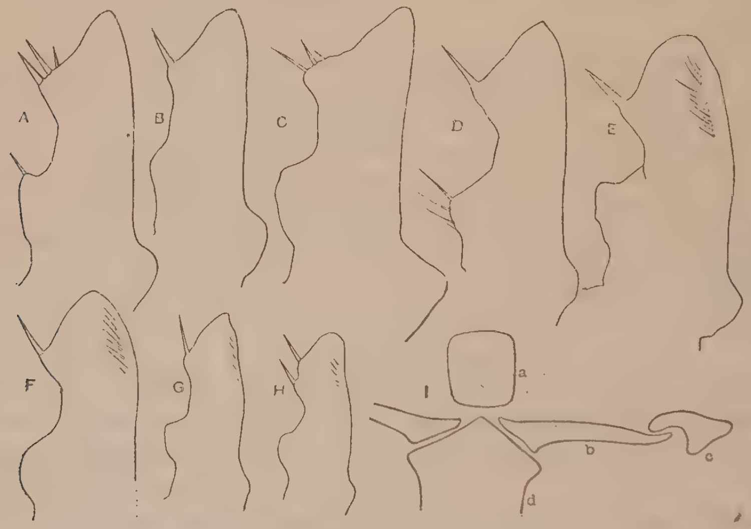

Fig. 148. Maxillulary palps (*A–H*) and stomodaeal ossicles (*I*) of *Metapenaeopsis*. *A* and *I*, *M. barbatus*, (*a*) cardiac, (*b*) pterocardiac, (*c*) prezygocardiac, and (*d*) anterior part of urocardiac ossicles; *B*, *M. acclivis; C, M. durus; D, M. dalei; E. M. incomptus; G, M. coniger; H, M. latus. A–C* and *E–H*, ×20; *D*, ×6; *I*, ×15.

Distribution: Mogi, Nagasaki Pref. (RATHBUN); Inland Sea of Japan (5–10 fathoms) (DE MAN); Near Tanabe, Wakayama Pref. (46 m); (YOKOYA); Kagoshima-Wan (URITA); Sashiki, Kumamoto Pref. OSADA, TANIZAKI and NAKAZAWA); Uraga (PARISI).

Note: The upper rostral spines are 6 or 7, mostly (89,4 %) 6 in number. The relative lengths, in relation to carapacial length, of the rostrum, sixth abdominal segment, and telson are positively isogonic, and those of the latter two items are equal to those of *M. barbatus* (Fig. 147, *A–C*). Thus, the length of the telson is not useful whatever for distinction of the present species from *M. barbatus*, though it has been given by YOSHIDA (*op. cit.*) as an important point for such purpose.

Proportion of the length of the sixth pleonic segment to its width measured at the middle is not different in both sexes of specimens, ranging 1.78–2.28, mostly 2.0–2.2 (Fig. 147, *D*).

The metamorhoses of petasma (Fig. 43, *A–J*), and thelycum (Fig. 0, *E* and *F*) are mentioned already elswhere.

The specimens on hand agree well with the original description and illustration especially in the conditions of rostrum, petasma and thelycum which are much valuable for distinction of the present form.

Penaeopsis akayebi of OSADA, TANIZAKI, and NAKAZAWA (1936) and of YOSHIDA (1941) may be probably identical with the present species judging from the rostral character.

The petasma as claimed by KISHINOUYE to be that of *Erythropenaeus akayebi* is, according to his figure (1929, p. 81), nothing more than that of *Metapenaeopsis acclivis* (=*Penaeopsis acclivis*), since the apical appendages of the left disto-ventral projection are in greatly pronounced condition.

PARISI's specimens of *Penaeopsis barbatus* (DE HAAN) reveal identity with the present species in the condition of the petasma as given in his Pl. 3, fig. 5.

Metapenaeopsis durus sp. nov.

(Figs. 8, *A*; 18, *G–L*; 22, *O*; 46, *D*; 64, *C*; 76, *E* and *J*; 80, *L*; 148, *C*; 149).

Penaeus veltinus, KISHINOUYE, 1900, Pl. 7. fig. 11 (Petasma).

Body tomentous. Rostrum styliform, hardly reaching midway of second antennular segment, considerably upcurved in distal half with apex directed forwards, about 6 times as long as wide measured at middle, armed above with 8 equidistant teeth besides epigastric one along its entire length, the hindmost one located a little behind frontal margin of carapace (Fig. 149).

Supra-orbital, antennal, pterygostomian, epigastric and hepatic spines present, the first of which is minute, and the rest moderate and subequal in size. Epigastric situated at a quarter of carapace. Hepatic set below epigastric and a little inferior to antennal spine. Post-ocular, orbito-antennal, cervical and hepatic grooves ill-defined. Hepatic groove runs upward form inferior third of distance between hepatic and pterygostomian spines, turns horizontally backward below hepatic spine, and reaches below about two-thirds of dorso-median line of carapace. Postrostral carina entirely absent backward to epigastric spine. Stridulating organ [illegible]-shaped, consisting of 28–35 bar-shaped ridges. Abdomen dorsally carinated posterior to first segment; the carina of second segment rather defined with smooth dorsal surface; that of third segment the most prominent, and becomes gradually a little wider backward with a well defined median groove, somewhat incised posteriorly for reception of the carina of fourth segment; those of fourth and fifth segments incised posteriorly at a considerable degree, and that of the fifth ends in a minute spine like that of sixth segment; terga of fourth and fifth segments produced rearward with acute apex on either side of the incision. Fourth pleonic segment without dorso-lateral subcarinae. Sixth pleonic segment has a minute tooth directed backward at postero-inferior angle, 1.7 times as long as wide measured at middle, two-thirds the length of carapace. Telson tapers into an acute tip, with shallow dorso-median groove, somewhat surpassing apex of inner uropods which surmount outer ones, quadruple as long as wide measured near base, armed with three pairs of movable and a pair of immovable dorso-lateral spines; the first pair of the movable placed at about half-way, immovable ones (the last pair) at about four-fifths.

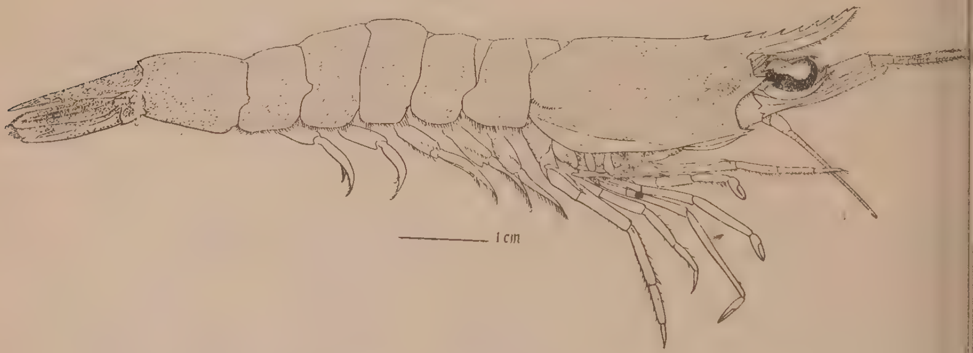

Fig. 149. *Metapenaeopsis durus* sp. nov., female, 81 mm long.

Eye carries a stout pointed spine directed anteriorly on upper dista margin of basal joint, somewhat lass than one-third the length of carapace in longer diameter of cornea. Prosartema extends as far as anterior end of eye. Stylocerite reaching well beyond far end of first antennular segment.

Antennular peduncle reaches tip of scaphocerite in male, surpassin scaphocerite by about half of third joint in female; first joint with stout plate-like protuberance on upper distal edge, and a sharply pointe spine directed antero-laterally; intermediate one twice the length of th third. Antennular flagella subequal in length, about half the length o carapace; upper ramus more or less thinner than the other. Scaphocerite thrice as long as wide measured at base, gradually narrows toward apex by one-third, has a disto-lateral spine which extends as fa as apex of lamella. Carpocerite rather short.

Mandible: molar process flattish and suboval on masticatory surface. Incisor process has a small notch near anterior end of cutting edge. Palp attains inner extremity of third antennal joint; the last joint subrhombic, bearing inner distal angle rather narrowly produced with rounded apex (Fig. 8, *A*). Maxillulary palp unsegmented, with narrowly rounded apex, having three protuberance, two on anterior and one on posterior edges as in *Metapenaeopsis barbatus* (Fig. 148, *C*). First maxilliped has comparatively shart endopodite which is five-segmented, with proportions in length to the last segment first 2.2, second 1, third 0.8, fourth 1.4. Second similar to that of *M. barbatus*. Third reaching to or beyond distal end of first antennular segment, proportions in length to dactylus: ischium 1.3, merus 1.3, carpus 1.7, propodus 14.

First pereiopod reaches to anterior end of basicerite, second to tip of carpocerite. Third extending as far as third maxilliped, proportion in length to movable finger: ischium 1.7, merus 3.7, carpus 5.9, propodus 1. Fourth extends as far as first leg; coxal plate remarkably developed, as large as anterior plate of thelycum (Fig. 46, *D*). Fifth attains far end of carpocerite, proportions in length to the last joint: ischium 1.5, merus 2.8, carpus 2.6, propodus 1.6.

Appendix masculina closely resembles that of *Metapenaeopsis barbatus* and *M. acclivis* in general configuration (Fig. 64, *C* and *C′*).

Petasma: right disto-ventral projection leaf-shaped, distally thickened, with about three spiniform apical appendages (Fig. 18, *K* and *L*, *a*); left distoventral projection markedly developed, furnished with about 15 pointed outgrowths on apical margin (Fig. 18, *I* and *J*, *e*); inner intermediate strip well-calcified, smooth, laterally compressed, subrectangular with rounded apex (Fig. 18, *J*. *g*); outer intermediate strip also laterally compressed with rounded apex, distally scabrous with rather thickly set short setae, much surmounting apex of inner intermediate strip (Fig. 18, *J*, *h*).

Thelycum strikingly similar to that of *A. acclivis*, but differs as follows: a large low medially somewhat depressed triangular swelling present behind transverse plate which is set on sternite between fourth pereiopods; posterior w-shaped transverse ridge more elevated at both postero-lateral angles (Fig. 46, *D*).

Stomodaeal ossicles intimately related to those of *M. barbatus* (Figs. 76, *E*, and *J*; 80, *L*).

Holotype: male, 77 mm long (17 mm in carapace-length).

Other two males, 76.1 mm and 94.5 mm long (17 mm and 22.3 mm in carapace-length), and two females, 81.1 mm and 84.1 mm long (19 mm and 20 mm in carapace-length), were also examined.

Locality: Tokyo (fish market); Miya, Aichi Pref.

Note: The present species is closely allied to *Metapenaeopsis* *barbatus* (De Haan) (=*Penaeopsis akayebi*) and *Metapenaeopsis acclivis*. But it is easily distinguished from them by the following characteristics: (1) rostrum distally upcurved with sharply pointed apex which is abruptly directed forward; (2) antero-lateral spines of carapace inserted at pterygostomian angle instead of lying somewhat upward to the angle; (3) stridulating organ made up of 28–35 ridges; (4) dorso-median carina of third abdominal segment with a well defined median groove; (5) fourth pleonic segment devoid of dorso-lateral subcarinae; (6) antennular flagella about half the length of carapace (two-sevenths in *M. barbatus* and *M. acclivis*); (7) antennal scale reaches to middle of second antennular segment in female; (8) all pereiopods somewhat shorter, third leg attains far end of first antennular segment; (9) apical appendages of left disto-ventral projection of petasma much more prominent than that of *M. barbatus*, and directed not irregularly as those of *M. acclivis*; (10) outer intermediate strip of petasma much larger than, and well surpassing, apex of the other. From *M. barbatus*, it is also easily recognizable by having much narrower anterior plate of thelycum as is the case with *M. acclivis*.

A Formosan species, *Metapenaeus barbatus*, recorded by Maki and Tsuchiya (*op. cit.*), bears close resemblance to the present species, but it differs, according to their description, in having straight rostrum, longer third pereiopods (reaching to apexes of scaphocerite) and fourth pereiopods of female without coxal plate.

Metapenaeopsis incomptus sp. nov.

(Figs. 8, *D*; 46, *A*; 76, *L* and *R*; 80, *N*; 148, *F*)

Penaeopsis lamellatus, Balss (part), 1914, p. 9, fig. 3.

Shell tomentous. Rostum styliform, horizontal with upper border straight, and lower one gradually upcurved in distal two-thirds, reaching about a third of intermediate article of antennular pedundle, has a lateral carina on either side, armed dorsally with 6 (exsept epigastric tooth) equidistant teeth along its entire length, the hindmost tooth set above postorbital edge. Carapace intimately resembles that of *Metapenaeopsis barbatus* (De Haan). Epigastric tooth situated at a fourth of carapace. Pterygostomian tooth as large as hepatic one which lies below the epigastric. Post-rostral carina and stridulating organ absent. Abdomen dorsally carinated posterior to first pleonic somite as in *Metapenaeopsis barbatus* and *M. acclivis*, but has no dorso-lateral subcarinae of fourth segment and terminal spinules of dorso-median carina of fifth segment. Sixth pleonic segment carries a spinule directed backward at post-inferior angle, 1.8 times as long as wide measured near posterior end, about 1.7

times the length of carapace. Telson attains apex of outer uropod, with three movable and a fixed spines in posterior half of each dorso-lateral margin as in *Metapenaeopsis barbatus*, about 0.8 times the length of carapace.

Eye has an acute scale directed anteriorly on upper distal rim of basal segment, about two-sevenths the length of carapace in longer diameter. Prosartema slender, extending as far as anterior end of eye. Stylocerite a little surpassing far end of basal antennular segment. Antennuler peduncle well exceeded by tip of antennal scale; basal joint has a sharp disto-lateral spine directed antero-laterally; intermediate two and half times the length of the last joint. Antennular flagella subequal in length and width, about a quarter the length of carapace. Basicerite with a rather large disto-lateral spine. Scaphocerite thrice as long as wide measured at base, tapers anteriorly by one-third, with a sharp antero-lateral spine which is well surmounted apex of lamella. Carpocerite short, 1.5 times as long as wide.

Mandible: molar process flattish on masticatory surface which is subrectangular in outline with corners rounded, with postero-median masticatory edge markedly produced into a pointed small teeth. Incisor process with a notch near anterior end of cutting rim. Palp very similar to that of *M. acclivis* (Fig. 8, D). Maxillulary palp unsegmented, bluntly pointed at apex, having two protuberances on anterior margin, distal one with a large spinous seta (Fig. 148, *F*). First maxilliped with rather broad exopodite narrowly rounded at apex; endopodite five-segmented, proportions in length to the last joint: first 1.5, second 0.45, third 0.5, fourth 0.75; first segment somewhat compressed, with five spinous setae near middle of inner border. Second as usual in shape; meropodite twice the width, somewhat lamellar on inner half, 1.7 times the length of dactylus. Third reaches to tip of antennal scale; ischium 1.3, merus 1.1, carpus 1.5 propodus 1.3 in relative length to dactylus.

First pereiopod extends beyond basicerite by chela: Second a little beyond far end of basal segment of antennular peduncle. Third reaching to middle of second antennuler segment, slenderer than third maxilliped, first and second pereiopods, proportions in length to movable finger: ischium 1.7, merus 3.1, carpus 4.8, palm 1.1. Fourth attains tip of carpocerite, with markedly developed. coxal plate (Fig. 46, *A*). Fifth reaching just beyond eye, more or less slenderer than the fourth, proportions in length to the last joint: ischium 13, merus 2.5, carpus 2.55, propodus 1.86.

Expodites of all maxillipeds and thoracic legs well developed; those of all pereiopods become gradually but slightly smaller backward, and that of the last leg extends to distal end of ischium.

Thelycum: a pair of abruptly pointed and antero-ventrally directed outgrowth present on sternite between third pereiopods; a large transverse plate lying on sternite between fourth pereiopods a little wider than long, minutely pointed at middle of apical margin, rounded at both disto-lateral angles, slightly depressed along median line of ventral (or posterior) surface; a pair of large low transverse swelling present just behind fourth pereiopods, bare, and medially coming almost into contact with each other with rounded inner ends; a conspicuous transverse ridge running on sternite between the last legs is present and has somewhat emarginate anterior edge, and a large pointed tooth at each lateral extremity; posterior rim of ultimate thoracic sternite furnished with three protuberances, median one of which minutely pointed at apex, much larger than lateral ones (Fig. 46, *A*).

Stomodaeal ossicles very closely related to those of *M. barbatus* and its allied forms. But equidistant spinules of cardiac plate are 28 in number, and teeth of postero-lateral edges of prepyloric ossicles relatively smaller, about 10 in number (Figs. 76, *L* and *R*, and 80, *N*) in the present species.

Type: a female, 70 mm long (19 mm in carapace-length).

Locality: East China Sea.

Note: As regards rostrum, BALSS's account of *Penaeopsis lamellatus* stands in harmony with *Metapenaeopsis* (=*Penaeopsis*) *lamellatus*, but his illustration for thelycum is, as already pointed out by PARISI (*op. cit.*), quite different from that of *M. lamellatus.* Thus, so far as this organ is concerned, confusion of two forms on his side is beyond doubt. Since his figure of it tallies completely with that of the present new species, a part of his material should be referred to *A. incomptus.*

The species newly erected here is very naer to *Penaeopsis mogiensis* (RATHBUN)(1), but may be distinguished from the latter by having the annexed features: rostrum horizontal, dorsally with 6 teeth exclusive of epigastric one, two spines set on sternite between second pereiopods not rudimentary; thelycum has a pair of large low transverse swellings just behind fourth pereiopods instead of having a pair of conspicus divergent median teeth; transverse ridge lying on sternite batween fifth pereiopods not laminar, simply tumid with somewhat emarginate distal edge and a short pointed tooth at each lateral end (with 4 protuberances with narrowly rounded apex on distal edge in *P. mogiensis*).

The thelycum of the present species is very similar to that of the young form of *Penaeopsis mogiensis* in feature of the transverse upheaval placed on the sternite between the fifth pereiopods, according to DE MAN(2) and SCHMITT(3). It also, resembles that of *Penaeopsis distinctus*

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(1) RATHBUN, 1902, pp. 39-40, figs. 6-8, 1906, p. 904, pl.20, fig. 3.
(2) DE MAN, 1911, p. 71, pl. 7, fig.22, candch (1913).
(3) SCHMITT, 1926, pp. 346-347, pl. 61, figs. 3 and 4.

(DE MAN)(4) as well as *Penaeopsis quinquedentatus* (DE MAN)(5). However, it differs from the former in lacking spinous projection behind the transverse plate laid down between the fourth pereiopods; and from the latter in possesion of two mucronate spines on the sternite between the third pereiopods and a large spine on each lateral edge of the transverse ridge running just in front of the posterior edge of the last thoracic sternite.

Metapenaeopsis dalei (RATHBUN)

(Figs. 1, *L*; 8, *H*; 22, *Q*; 33, *A–J*; 46, *E*; 64, *D* and *D′*; 76, *K* and *Q*; 80, *M*; 148, *D*).

Penaeopsis dalei, YOSHIDA, 1941, p. 15, text-fig. 7, pl. 3, fig. 1.
Parapenaeus dalei, RATHBUN, 1902, pp. 40-41, figs. 9-11.
Ceratopenaeus dalei, YOKOYA, 1930, p. 527; 1933, pp. 6-7.

Carapace (except stridulating-organs) and abdomen intimately resemble that of *Metapenaeopsis barbatus* (DE HAAN) and *Metapenaeopsis acclivis* (RATHBUN), but dorso-median carina of fifth pleonic segment less elevated and not ending in minute spine, and telson hardly reaching apexes of uropods or somewhat exceeded by them.

Eye rather large, about two-sevnths the length of carapace in longer diameter of cornea. Antennal peduncle a little surmounted by antennal scale; intermediate joint somewhat more than thrice the length of third joint. Antennular flagella subequal in length, ca. 0.27 times as long as carapace; upper (or inner) ramus thinner than the other. Mandible similar to that of *Metapenaeopsis incomptus* in general aspect (Fig. 8, *H*). Maxillulary palp closely resembles that of *M. barbatus* (Fig. 148, *D*). First maxilliped with rather broad (ca. 5 times as long as wide) exopodite with narrowly rounded apex; endopodite five-jointed, surpassing apex of exopodite by the last joint, proportions in length to fifth joint: first 2, second 0.5, third 0.7, and fourth 1. Second maxilliped normal in shape; merus lamellar on inner half, twice as long as wide, 1.7 times the length of dactylus. Third maxilliped hardly reaches to or slightly beyond tip of second antennular segment, proportions in length to dactylus: ischium 1.4, merus and propodus 1.36, carpus 1.8.

First pereiopod surpassing basicerite by half of chela. Second stretches beyond carpocerite by half of chela. Third reaching about middle of second antennular segment, ratios in length to movable finger: ischium 1.6, merus 3.2, carpus 5, propodus 1.1. Fourth attains half-way of carpocerite, with rather developed coxal plate. Fifth reaches slightly beyond carpocerite, proportions in length to dactylus: ischium 1.3, merus 2.4, carpus 2.6, propodus 1.6.

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(4) DE MAN, 1911, pp. 69-70, pl. 7, fig. 21 (1913).
(5) DE MAN, 1911, pp. 71-73, pl. 7, fig. 23*a–d* (1913).

Sternite of fifth thoracic somite has a pair of slender sharply pointed spines, that of the sixth has a pair of short mucronulate projections like that of *M. incomptus*.

Appendix masculina very similar to that of *M. barbatus* and its congeners, but apical surface lunate in outline (Fig. 64, *D* and *D'*).

Petasma*: right disto-ventral projection strikingly thickened toward tip, bare, rounded at apex, devoid of appical appendages; disto-ventral flap exceeded by a third of right disto-ventral projection, less developed compared with that of *M. acclivis* and *M. durus;* left disto-ventral projection slender, carries about five apical outgrowths (two or three of which simply pointed, and the rest minutely bifid at apex) overlapping apex of right disto-ventral projection (Fig. 33, *I* and *J*).

Thelycum made up of a large transverse plate arising form sternite between fourth pereiopods, a pair of sunken bosses behind the transverse plate, a transverse ridge with a prominent acute spine at each lateral end, and three teeth lying on posterior ridge of the last thoracic sternite. The transverse plate directed antero-ventrally, subrectangular in outline, minutely pointed at middle of distal edge and at each disto-lateral angle. Teeth of posterior ridge of the last thoracic sternite compressed with acuminate apex, median one of which very conspicuous (Fig. 46, *E*).

Stomodaeal ossicles closely related to those of *M. barbatus*, ecep that cardiac plate bears 16–18 spinules (Figs. 76, *K* and *Q;* and 80, *M*).

The description and figures are based on males and females abou 70 mm long (17 mm in carapace-length). A lot of specimens, 23 males, 45.4–73.0 mm long (11.0–18.9 mm in carapace-length), and 34 females, 47.0–76.3 mm long (11.7–21.4 mm in carapace-length) were also examined.

Locality: Tyôshi, Chiba Pref.; Miya, Aichi Pref.; and Kagoshima.

Distribution: Mogi, Nagasaki Pref.; Hakodate, Hokkaidô (RATHBUN); Mutu Bay; Kinkazan to Bungo Strait; Gotô Is., Koshiki Is. (Kyûsyû); Oki Is., Mihonoseki, Simane Pref.) (33–132 m) (YOKOYA); West coast of Tyôsen (YOSHIDA).

Note: The rostral spines vary in number within a range of 5 to 8 as follows:—

Number of spines	5	6	7	8
Frequency	3	31	18	1
Percentage	5.6	58.4	33.9	1.8

The rostrum, eyes, antennular flagella and pereiopods undergo a little age-variation.

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* Metamorphosis of this organ is given in general part of this paper (Fig. 33).

The rostrum is inclined more upward and shorter in younger speci- ens: that of specimens smaller than about 50 mm long (12 mm in rapace-length) is hardly reaching to distal end of the first antennular gment.

The proportion of the longer diameter of cornea to the length of rapace become gradually smaller with age, viz., It is 0.36, 0.29, and 25 in the animal measuring about 45.4 mm, 70 mm, and 76 mm respect- ely in body-length (11 mm, 17 mm, and 21 mm in carapace-length).

The antennular flagella are a trifle longer in younger specimens, 35, 0.31, 0.27, and 0.25 times the length of carapace in specimens, 49.9 m, 57.4 mm, 71.0 mm and 76.3 mm long (11.7 mm, 13.6 mm, 17.5 mm nd 21.4 mm in carapace-length) respectively.

The pereiopods, especially posterior three, appear relatively longer in venile specimens. The third limb reaches to the distal end of second tennular segmet, those of the fourth and fifth pairs surpassing the rpocerite by about dactylus in specimens smaller than ca. 50 mm long.

All specimens are well in agreement with the descriptions and ures given by RATHBUN and YOSHIDA, who, however, overlooked the sto-lateral spinules of the anterior plate of the thelycum and the lateral ines of the transverse ridge lying on the sternite between the fifth reiopods.

Metapenaeopsis lamellatus (DE HAAN)

(Figs. 1, *K*; 8, *E*; 34, *A-F*; 46, *F*; 64, *F* and *F'*; 76, *O* and *U*; 81, *C*; 148, *E*).

Penaeopsis lamellatus, PARISI, 1919, pp. 62-63; pl. 5, figs. 2, 4, and 9; HIRUMA, 1925, p. 425, fig. 7; OSADA, TANIZAKI, and NAKAGAWA, 1936, p. 9, pl. 4, upper (left); YOSHIDA, 1941, p. 14, pl. 13, fig. 2.

Penaeus lamellatus, DE HAAN, 1850, p. 193, pl. 46, figs. 4 and 5; MIERS, 1878, p. 308; KISHINOUYE, 1900, pp. 25-26, pl. 6, fig. 1, and pl. 7, fig. 12; DOFLEIN, 1902, p. 631.

Penaeus (*Metapenaeus*) *lamellatus*, DE MAN, 1907, p. 432.

Metapenaeus lamellatus, URITA, 1921, p. 215.

Parapenaeus lamellatus, RATHBUN, 1902, p. 38.

Penaeopsis lamellatus, (part) BALSS, p. 9, fig. 3.

Carapace without postrostral carina in posterior third. Epigastric th stands a little backward to middle of carapace. Hepatic lies below e rearmost rostral spine and considerably inferior to the level horizon- through antennal one. Branchiostegal spine inserted on antero-lateral rgin of carapace and considerably above pterygostomian angle. Abdo- n with dorso-median carina posterior to first somite; the carina of ond somite very low with smooth upper surface, that of third somite st salient, posteriorly incised as that of fourth and fifth ones, and that of sixth somite sharply pointed at posterior end; tergun of secon somite rather broadly at middle of posterior edge; sixth somite with spinule directed posteriorly at postero-inferior angle, 1.3 times as long a wide measured at middle, about half the length of carapace. Telso more or less surmounted by uropods, ca. 1.2 times the length of sixt pleonic somite, armed with movable (anterior) and immovable (the last spines on each dorso-lateral margin, first of which located near half way of it.

Eye about a third the length of carapace in longer diameter o cornea. Prosartema and stylocerite extending a little beyond distal en of first antennular peduncle. Antennular peducle attains apex of antennal scales; basal segment has a plate-like upstanding protuberance o disto-dorsal edge besides a sharp disto-lateral spine; second segment on and half times the length of third segment. Antennular flagalla asym metrical; upper (or outer) ramus gets abruptly filiform, thicker an shorter than the other; lower one tapering, ca. 0.5 times in male an 0.35 times in female the length of carapace. Basicerite has an acut spine directed on distal outer margin. Antennal scale twice as long a wide measured at base, narrowed anteriorly by one-third, with a dist lateral spine slightly surpassing apex of lamella. Carpocerite extendir as far as middle of basal antennular segment, twice as long as wide.

Mandible: molar process lunate, rugged on masticatory surfac with sharp and somewhat produced inner masticatory edge. Incisor o bears anteriorly two teeth on cutting rim. Palp broader than that of a the preceding species of *Metapenaeopsis;* distal joint wider than lon disto-medially produced with rounded apex, reaching to inner distal en of third antennal sagment (Fig. 8, *E*). Maxillulary palp near to that c *Metapenaeopsis incomptus* (Fig. 148, *E*). First maxilliped with rath broad exopodite which tapers into a very nerrowly rounded apex in sul terminal portion; endopodite five-segmented, proportions in length to th last joint: first 1.2, second and third 0.5, fourth 0.6. Second inverted shaped: meropodite lamellar in inner half, 1.8 times as long as wid 1.5 times the length of dactylus. Third reaches to or a little beyond t of antennal scale; ischium and merus 1.4, carpus 1.6, propodus 1.2 proportion to dactylus.

First pereiopod surpassing carpocerite by half of chela. Secon reaches to tip of antennular peduncle. Third stretching beyon scaphocerite by half of chela, proportions in length to movable finge ishium 1.1, merus 2.1, carpus 3.4, palm 0.94. Fourth attains apex c carpocerite, carries a rather developed coxal plate with a spinous proces at antero-median angle in female (Fig. 46, *F*). The last reaches beyon carpocerite by dactylus; ischium 1.5, merus 2.4, carpus 2.6, propodu 2.1 in relative length to dactylus.

Exopodite well-developed in all thoracic appendages, that of third axilliped reaching to mid-way of carpus, that of first pereiopod to far d of its meropodite, although those of succeeding pairs so much crease their length by degrees that last pair slightly surpasses ischium.

Sternite of fifth thoracic segment has a pair of acicular spine in th sexes.

Appendix masculina very similar to that of preceding species of this nus (Fig. 64, *F* and *F′*).

Petasma: right disto-ventral projection rounded at apex, with a ge sharply pointed apical appendage; disto-ventral flap well-developed; t disto-ventral projection concavo-convex with nude convex outer rface, bearing one larger (as large as that of the right projection) and e or two smaller acuminate apical appendags, much larger than the ht; left internal piece markedly expanded and thickened, extending far as left distoventral projection, as in *Metapenaeopsis dalei* (Fig. , *A–F*).

Thelycum consists of anterior and a posterior plates, and an anter and a posterior transverse ridges. Anterior plate laid down on rnite between third pereiopods, tongue-like, directed anteriorly. Poster plate placed on sternite between fourth legs, subrectangular with a ge acicular spine at middle of distal margin and rather sharply defined to-lateral angles. Anterior transverse ridge set on sternite between h pereiopods, having a pair of prominent tumid median protrusions th round apexes directed anteriorly, and a lamellar protuberance with ually rounded apex directed antero-ventrally at each lateral end. sterior ridge raised from posterior rim of the last thoracic sternite, d has a small pointed median spine besides a pair of large lateral minar expansions with rounded apex directed more or less anterontrally (Fig. 46, *F*).

Stomodaeal ossicles intimately related to those of *Metapenaeopsis batus*, except the following pointe: cardiac plate has 24–26 equidistant nules, prepyloric ossicle about 8 disto-lateral teeth, first 3 or 4 of ich much smaller than the rest (Figs. 76, *O* and *U*; 81, *C*).

The description given above is based on a male, 66.3 mm long (14.9 n in carapace-length) and a female, 69.1 mm long (17.0 mm in carapacegth). Moreover, 6 males, 52.0–59.0 mm long (11.8–13.8 mm in carae-length), and 13 females, 34.0–74.8 mm long (8.6–18.9 mm in carapacegth) were also examined.

Locality: Tokyo (fish market); Miya, Aichi Pref.; Ushimado, Okaya- Pref.; Tomo, Hiroshima Prof.

Distribution: West-coast of the Island of Jezo, near Cape Soja, lat. ' (De Haan); Nagasaki (Rathbun); Inland Sea of Japan (De Man); kkaidô to Kyûsyû (Kishinouye); Sagami Bay, Bôsyû, Gotô Is.

(Parisi); Kagoshima-Wan (Urita); Sashiki, Kumamoto Pref. (Osada Tanizaki, and Nakazawa).

Note: The dorsal rostral spines range from 7 to 10 (mostly 8 excluding the epigastric one, posterior 3 or 4 of which are placed o carapace, irrespective of sex and size of the animal.

The proportion of longer diameter of cornea to the length of cara pace becomes smaller with age. It is 0.5 in the smallest specimen famale, 34 mm long (8.6 mm in carapace-length), 0.4 in a female, 43.5 mm (10.4 mm), 0.3 in larger specimens than about 65 mm in length (16.5 mm in carapace-length).

The antennular flagella of male are longer than those of female. S far as the present investigation goes, the inner (or lower) ramus is 0.42 0.60, and 0.29–0.35 times the length of the carapace in male and femal respectively.

The third chelipeds appear to be proportionally longer in younge specimens. They are found reaching beyond tip of the antennal scal by entire chela in specimens smaller than about 50 mm in body-lengt (ca. 11 mm in carapace-length).

The specimens at the writer's disposal tally nearly completely wit the descriptions and illustrations given by De Haan, Kishinouy Doflein, De Man, Parisi, Hiruma, and others, except Kishinouye Fig. 12, in which the characteristic apical appendages of both the righ and left disto-ventral projections of the petasma are not depicted.

Metapenaeopsis coniger (Wood-Mason)

(Figs. 8, *F*; 35, *A–H*; 46, *H*; 64, *E* and *E'*; 76, *M* and *S*; 81, *A*; and 148, *G*).

Metapenaeus coniger, Wood-Mason, 1891, p. 272. Alcock, 1901, p. 16.

Metapeneus coniger, Alcock, 1906, pp. 24–27, pl. 4, figs. 12 and 12*a*, *b*.

Post-rostral carina attains middle of caradace, although not salien Epigastric tooth situated at a quarter of carapace. Hepatic tooth stand slightly backward to the epigastric and more or less below antenn spine, somewhat larger than the epigastric. Branchiostegal tooth raise from anterior margin of carapace. Abdomen dorsally crrinated posteri to first segment; each tergum of fourth and fifth segments has a medi incison posteriorly and a pointed projection on each side of the incisio sixth with a spinule directed backward at postero-inferior angle besid that lying at posterior end of dorso-median carina, 1.8 times as long a wide measured at middle, 0.8 times the length of carapace. Telso extending as far as inner uropods which are much surmounted by oute ones, armed with three pairs of movable and a pair of fixed (rearmos dorso-lateral spines, the first pair placed a little posteriorly to middle.

Eye bearing a calcified scale directed forwards on disto-dorsal edg basal joint; a little less than a third the length of carapace in longer ameter of cornea. Prosartema and stylocerite as in *Metapenaeopsis* *mellatus*, although a little feebler. Antennular peduncle stretches to p of scaphocerite; basal joint has an appendage with rounded apex rected upward on distal upper border; second joint two and half times long as the third. Antennular flagella different in length; upper mus two-thrids the length of the other, lower ramus about 0.7 times male and 0.5 times in female the length of carapace, and has a coni- l tubercle at one-fourth in male. Scaphocerite 3.5 times as long as ide measured at base, narrowing anteriorly by half, with a disto-lateral ine produced as far as apex of lamella. Carpocerite attains below iddle of cornea, twice as long as wide.

Mandible: molar process flattish, elliptical on masticatory surface, cisor one with a notch near anterior end of cutting edge; palp closely sembles that of *Metapenaeopsis durus* (Fig. 8, *F*). Maxillulary palp usual in feature (Fig. 148, *G*). First maxillipid with rather broad opodite simillar to that of *Metapenaeopsis dalei* in general aspect; opodite five-segmented, proportions in length to the last joint: first 1, second 1, third 1.2, fourth 2.

Second normal in shape; meropodite twice the width, 1.5 times the ngth of dactylus. Thrid reaching to tip of antennular stalk, ischium 7, merus 1.6, carpus 1.9, propodus 1.3 in proportion to dactylus.

First pereiopod stretches to tip of carpocerite. Second surpassing r end of first antennular segment by finger. Third extends as far as ter maxilliped, proportions in length to movable finger: ischium 1.9, erus 3.8, carpus 5.8, palm 1. Fourth surmounting antennal peduncle half of dactylus, and has a rather developed coxal plate. Fifth retching as far as second leg, proportions in length to the last joint: chium 1.3, merus 3.1, carpus 2.7, propodus 1.8.

Appendix masculina very similar to that of all preceding forms of is genus, but apical surface ovoid in outline (Fig. 64, *E* and *E'*).

Petasma near to that of *M. lamellatus;* right disto-ventral projec- on rounded at apex which bears several pointed spinules, extending as r as disto-ventral flap; left disto-ventral projection resembles right sto-ventral one in feature, with about 8 apical spinules (Fig. 35, *A–H*).

Thelycum made up of a broad T-shaped median plate and a pair of verted L-shaped lateral ridges, Median plate rounded at antero-lateral gles, double convex on posterior edge, provided with a narrow T- aped groope on outer surface. L-shaped ridge with antero-lateral end ising just behind coxal plate of fourth pereiopod, and with posterior d reaching to lateral protuberance of posterior edge of the last tho- cic sternite (Fig. 46, *H*).

Stomodaeal ossicles closely allied to those of *M. barbatus*, but with the following differences: cardiac plate with 25–27 spinules; zygocardiac ossicle with two large conical teeth alone; and prepyloric has about smaller teeth on each post-lateral margin (Figs. 76, *M* and *S*; and 81 *A*).

The aforementioned description is based on a male 72.6 mm long (16.5 mm in carapace-length), and a female, 71.0 mm long (17.5 mm i carpace-length). Other 3 males and 10 females, meauring 48.0–68.2 mm long (11.0–16.5 mm in carapace-length) were also examined.

Locality: Off Maisaka, Sizuoka Pref. (ca. 150 m); off Nagashima Mie Pref. (ca. 230 m); off Kochi (Shikoku).

Distribution: Off East coast of India (58–250 fathoms); Andama Sea (ALCOCK).

Note: The upper rostral spines vary. from 6 to 8 (mostly 7) i number.

The proportion of longer diameter of the cornea displays no difference with size of body, so far as the present material is concerned.

The antennular flagella are sexually dimorphic not only in shap but also in length. These are longer in male than in female: the lowe flagellum is 0.71–0.73 times and 0.53–0.63 times the length of the carapace in male and in female respectively. But this dimorphism seems t become clear in specimens larger than about 55 mm long (ca. 13 mm i carapace-length).

All the present specimens quite tally with the description a figures *Metapenaeus coniger* given by ALCOCK, but differ distinctly fro *Penaeopsis coniger* var. *andamanensis* (WOOD-MASON)(1) as defined b him in shape of the median plate of the thelycum.

The present species is very intimately related, if not identical wit to *Penaeus philippinensis* BATE. Nothing is known of the followin characters of *M. coniger* in *P. philippinensis*, viz., the lower antennula flagellum of male has a tubercle, and the T-shaped median plate of th thelycum is without a notch on each lateral edge of the vertical portio of the T.

Metapenaeopsis latus sp. nov.

(Figs. 8, *G*; 46, *G*; 76, *N* and *T*; 81, *B*; 148, *H*; 150)

Rostrum acicular, straight, slightly uptilted, reaching a little beyon distal end of second antennular segment, with a lateral ridge on bot sides, armed with seven equidistant teeth above, the last one locate somewhat anterior to post-orbital margins of carapace and the foremos

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(1) WOOD-MASON, 1891, p. 271; ALCOCK, 1901 p. 17; 1906, p. 27, Pl. 4, fig. 13; DE MA 1911, pp. 61–62, PARISI, 1919, p. 64, Pl. 5, fig. 7.

e at about middle between the tip and second tooth, about 0.8 times e length of carapace. Postrostral carina not defined. Post-ocular, bito-antennal, and cervical grooves hardly recognizable. Epigastric, praorbital, antennal, hepatic and pterygostomian spines present. Epi- stric situated at a quarter of capapace. Hepatic inserted slightly back- ard to epigastric spine and more or less inferior to antennal one. terygostomian spine very sharp, directed antero-ventrally. Sixth thora- c sternite has a pair of short pointed spines. Abdomen dorsally cari- ted from second to sixth segment; the carina of second segment fined in anterior half, that of third segment distinct in posterior two- irds and shallowly incised posteriorly, those of fourth and fifth segments so posteriorly incised in considerable degree, and that of sixth segment lminates in a pointed spinule. First pleonic segment minutely notched middle of anterior margin of tergum; fourth and fifth ones have a all acuminte process on either side of the incision and a pair of rso-lateral subcarinae; sixth one with a spinule at postero-inferior gle, 2.5 times as long as wide measured at middle, 0.8 times the length carapace. Telson tapering into a sharply pointed tip, a little more an 4 times the broadest width, with a shallow dorso-median groove d has a pair of lateral prongs at about a third, armed with three irs of movable dorso-lateral spines and a pair of fixed spines behind ovable ones, the first pair placed a little posterior to middle, somewhat ceeded by inner uropods.

Eye has an acute scale on disto-dorsal edge of basal segment, one- ird the length of carapace in longer diameter of cornea. Antennular duncle including prosartema and stylocerite equal to that of *Meta- naeopsis coniger* except second segment which is twice the length of e third. Antennular flagella both cylindrical, simply tapering, but fferent in length, upper ramus two-thirds as long as the other which easures 0.66 times the length of carapace. Antennal scale reaches a ifle beyond tip of antennular stalk, thrice as long as wide measured base, anteriorly narrowed by two-fifths, bearing a disto-lateral tooth hich extends as far as apex of lamella. Carpocerite attains below mid- e of cornea. Antennal flagella 1.1 times the length of body.

Mandible resembles that of *Metapenaeopsis coniger* (Fig. 8, *G*). axillulary palp with two spinous setae on subterminal anterior rim ig. 148, *H*). First maxilliped having rather broad exopodite with terior apex ogival in outline; endopodite five-segmented, proportions length to the last article: first 2.9, second third 0.9, fourth 1.1. Second usual in shape, meropodite 2.1 times the width, 1.8 times the length of actylus. Third hardly reaching to tip of antennular peduncle, ischium d merus 1.8, carpus 2.1, propodus 1.4 in proportion to dactylus.

First pereiopod stretches slightly beyond carpocerite. Second reaching to far end of first segment of antennular segment. Third extends as far as third maxilliped, with a markedly developed coxal plate, proportions in length to movable finger: ischium 1.3, merus 4, carpus 6, palm 1. Fourth extends as far as first leg, and has a spatulate coxal plate (Fig. 46, *G*). The last attains distal end of basal antennular segment, proportions in length to dactylus: ischium 1.3, merus 2.8; carpus 2.7, propodus 1.8.

Uropods rather slender, outer one much longer than the other, with a disto-lateral spinule which is greatly surmounted by rounded apex.

Thelycum consists of two broad plates: anterior plate remarkably tumid, rectangular with all lateral angles rounded, lateral borders markedly concave, and posterior border which gives off a pointed median salience; posterior plate much wider than anterior one, medialy indent and has an auriculate elevation at each antero-lateral angle (Fig. 46, *G*).

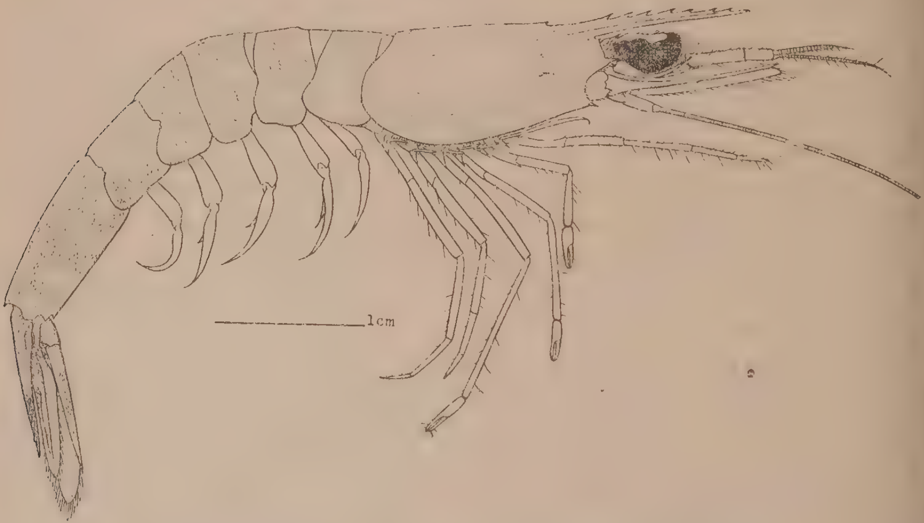

Fig. 150. *Metapenaeopsis latus*, sp. nov., female, 59 mm long.

Cardiac plate with 27–29 spinules. Cardiac, pterocardiac, and urocardiac ossicles very similar to those of *Metapenaeopsis barbatus*. Zygocardiac with two conical teeth alone as in that of the just preceding species (Fig. 81, *B*). Prepyloric furnished along each postero-lateral edge with about 10 pointed teeth which are shorter compared with those of *Metapenaeopsis barbatus*, and its allies (Fig. 76, *N* and *T*).

Holotype: female, 59 mm long (14.5 mm in carapace-length).

Paratype: three females, 13.0–15.2 mm in carapace-length which are mutilated in rostrum, distal portion of telson, and antennal flagella.

Locality: Off Nagashima (ca. 350 m), Mie Pref.

Note: The present species is very closely allied to *Penaeopsis yushuensis* YOKOYA,(1) but it may be separated from the lattter by the ollowing characters: the abdomen dorsally carinated posteriorly to first egment instead of posterior to second segment; the posterior protrusion f the anterior plate of the thelycum is smaller, not extending to the osterior margin of the last thoracic sternite. Besides these, the branhial arrangement of *Penaeopsis kyushuensis* YOKOYA appears greatly iscrepant in having a pleurobranchia on the second thoracic segment, nastigobranchia on the seventh, and no arthrobranchia on the seventh. ut the mastigobranchia is not represented and the arthrobranchia apparntly delineated on his Text-fig. 2, *B*.

Again the present species is closely related to *Penaeopsis sibogae* DE MAN),(2) but easily distinquished from the latter by having shorter ostrum, and a pointed median projection on posterior rim of the anteor plate of the thelycum.

Subfam. *Eusicyoninae* BOONE

Eusicyoninae, BOONE, 1930, p. 115; BURKENROAD, 1934*a*, pp. 116-120; 1934*b*, p. 70.
Sicyoninae, ORTMANN, 1890, p. 453; A. MILNE-EDWARDS and BOUVIER, 1909, p. 243; DE MAN, 1911, p. 111; BALSS, 1914, p. 14; 1925, p. 232.

Genus *Eusicyonia* STEBBING (emend)

Eusicyonia, STEBBING, 1914, p. 25; BALSS, 1925, p. 232; BURKENROAD, 1934*a*, p. 121; 1934*b*, pp. 70-76; 1938, p. 80.
Sicyonia, H. MILNE-EDWARDS, 1830, p. 339; 1837, pp. 408-409; DE HAAN, 1850, pp. 187 and 189; HELLER, 1863, p. 290; BATE, 1888, pp. 292-294; RATHBUN, 1902. p. 103; DE MAN, 1911, pp. 111-113; BALSS, 1914, p. 14; PESTA, 1918, p. 46.

Rostrum short with teeth. Antero-inferior angle of carapace not piniform. Cervical and hepatic grooves ill-defined or not marked at all. ost-rostral carina well-defined with teeth. Antennal spine present or bsent, the hepatic present. Abdomen sculptured on lateral walls, dorally carinated, the carina of first segment raised into an acute tooth, hat of the second transversely notched or entire, that of the fifth somite erminating posteriorly in a spine or sharp angle, and that of the sixth orms a spine at posterior end; pleura with or without spines on inferior nargin. Telson with a dorso-median sulcus, dorso-lateral edges, and lways with fixed spines but rarely with movable spinules. Basal ocular eduncle with an acicular spine. Prosartema very rudimentary. Antenular flagella short. Maxillulary palp unsegmented. Maxilla is of Type-

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1) YOKOYA, 1933, pp. 5-6, text-fig. 2 (*A-D*).

2) DE MAN, 1907, p. 131; 1911, pp. 63-64, Pl. 6, figs. 18, 18*a-h* (1913).

G_3. Posterior two maxillipeds and all pereiopods without exopodite. First pereiopod with or without basial and ischial spines. Pleopods devoid of endopodites except those of second pair of male in which they persist rudimentarily.

Petasma depressed, subrectangular in outline, with apical processes. Thelycum made up of two flattish plates.

A pleurobranchia present on each second and third thoracic segment. A rudimentary arthrobranchia lies on the first and the seventh, that of the first without filaments, and that of the seventh filiform; an entire one on the second and the seventh; and two ones on the segments of the third to the sixth. A podobranchia exists on the second. A mastigobranchia appears on the first, second, and the fourth to sixth (Table 6, *O*).

Note: Besides the above-mentioned characters the following items are found common in all the examined Japanese species:—Rostrum with a lateral ridge on each. Antennal spine absent. Dorso-median carina of second to fifth pleonic segments rather deeply incised at posterior end, that of the fifth without sharp angle or spine at posterior end. Telson stretching slightly or somewhat beyond apexes of uropods. Stylocerite extends well beyond apex of eye. Basal antennular segment with an acicular spinul at disto-lateral angle. Antennal flagella somewhat longer than half of body-length. Molar process of mandible flattish on masticatory surface, incisor one unarmed along cutting edge. First pereiopods have both basial and ischial spines, the second the former only. Inner and outer uropods subequal in length, but the latter somewhat wider than the former. Thelycum carries an acicular spine on apex of anterior plate; posterior plate flat, much wider than the other. Cardiac plate with spinules less than 15 in number. Cardiac ossicle subrectangular. Pterocardiac simply bar-shaped. Prezygocardiac small, arc-shaped in outline. Prepyloric ends into a large pointed median tooth which is much larger than those set along its postero-lateral edges. Mastigobranchia asymmetrically bifurcate at apex.

Special interest attaches to the antennal spine, dorsomedian carinae of second and fifth abdominal segments, and basial and ischial spines of first pereiopods. In some American species (BURKENROAD, 1934 b, pp. 71–76), a minute antennal spine is present; the carina of the second segment with a transverse notch, that of the fifth culminating posteriorly in a spine or sharp corner; and the spines of the first pereiopods absent. These are, however, not observed in our specimens as given in the paragraph just above.

Remarkably enough, the telson of *E. inflexa*, sp. nov. is provided with many pairs of movable spinules in addition to a pair of fixed ones. This fact, highly valuable for interpretation of the phyletic relation, was pointed out by STEBBING(1) in *E. longicauda* (RATHBUN)(2) only. The branchial arrangements of all the species at the writer's disposal agree with that given by BURKENROAD (1934 a, p. 117) except the vestigial simply membranous arthrobranchia attached to the first thoracic segment, which was verified by him to exist but he did not formulate it.

The present genus differs greatly from other genera dealt with in many peculialities: abdomen sculptured on lateral walls, basal ocular segments with acicular spines, prosartema very vestigial, exopodites of thoracic appendages from second maxilliped to the last pereiopod and endopodites of pleopods excluding those of second pleopods of male are absent, pleurobranchiae only two in number, and anterior arthrobranchia of seventh thoracic somite rudimentary. Basing on the second character this genus has been regarded linked with Aristaeinae by previous investigators except BURKENROAD (*op. cit.*) who believed that it is rather greatly nearer to Penaeinae than to Aristaeinae from comparision of larval development of these penaeids. Since Eusicyoninae stands close to Penaeinae in features of petasma, thelycum, appendix masculina as well as in the absence of mastigobranchiae (except *Penaeus* in which the branchiae in question are present as in Aristaeinae), BURKENROAD's conception is justified. It is of interest that the present genus is near to *Parapenaeopsis*, *Trachypenaeus*, *Atypopenaeus*, and *Miyadiella* in zygocardiac ossicle; to *Parapenaeus*, *Metapenaeus*, *Atypopenaeus*, and *Metapenaeopsis* in appendix masculina; and to *Metapenaeopsis* in mandibular palp.

At present about 25 species and varieties are know, 15 from Indo-Pacific, 5 of which have been known from our waters. In this paper, four new forms are added to the Japanese fauna. But unfortunately the following three known species: *E. bispinosa* (DE HAAN), *E. parvula* (DE HAAN), and *E. lancifer* (OLIVIER), are not represented in our material. The key given below is made for all the Japanese species.

Key to the Japanese species of the genus *Eusicyonia*.

A₁ Abdominal pleura of first four segments with sharply pointed spines

B₁ Abdominal pleura of second segment unispinose ....*E. lancifer* (OLIVIER). Post-rostral carina with 6 teeth; hepatic spine moderate in size; abdominal pleura of second and third segment unispinose; eyes one-fourth the length of carapace in longer diameter of cornea; dorsal distomedian processes of petasma pointed at apex, ventral disto-lateral ones with abruptly pointed tip directed postero-laterally and semicircularly rounded anterior borders; median hollow of thelycum as long as wide ....*E. lancifer japonica* (BALSS).

B₂ Abdominal pleura of second segment with two spines, those of the third with two or three ones; post-rostral carina with four teeth; hepatic spine remarkably large; eyes a fifth the length of carapace in longer diameter of cornea; dorsal disto-median processes of petasma truncate at apex, ventral disto-lateral ones with narrowly rounded apex directed antero-laterally and straight anterior border running obliquely forwards; median hollow of thelycum much wider than long ....*E. cristata* (DE HAAN).

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(1) STEBBING, 1914, p. 26, pl. 73.

(2) RATHBUN, 1906, p. 908, pl. 20, fig. 6.

A_2 Abdominal pleura of first four segments without spines

C_1 Rostrum horizontally straight; post-rostral carina remarkably elevated, furnished with four teeth; anterior plate of thelycum assumes the outline of violin ....*E. vitulans* sp. nov.

C_2 Rostrum considerably curved upward; post-rostral carina moderately defined, armed with two teeth (excluding that lying a little behind post-orbital edge); anterior plate of thelycum(1) inverted funnel-shaped in outline or lanceolate in outline

D_1 Rostrum reaching to or slightly beyond distal edge of first antennular segment, less than thrice as long as wide measured at anterior base of the rearmost rostral spine

E_1 Rostrum curved forwards in distal about one-third; sixth abdominal segment as long as wide; cardiac plate with 12–14 spinules ....*E. curvirostris* (BALSS).

E_2 Rostrum straight; sixth abdominal segment much longer than wide (1.3–1.5 times as long as wide); cardiac plate carries 4–7 spinules

F_1 Rostrum pointed at apex; thelycum with a median hollow between anterior and posterior plates, the anterior plate notched on lateral borders near posterior end ....*E. nebulosa* sp. nov.

F_2 Rostrum truncate at apex; thelycum devoid of median hollow, the anterior plate without notches on lateral borders ....*E. truncata* sp. nov.

D_2 Rostrum reaching to at least distal end of second antennular segment, more than thrice as long as wide measured at anterior base of the rearmost rostral spine

G_1 Sixth abdominal segment one and half times as long as wide; with movable spinules; rostrum usually recurved upward, apical spines directed anteriorly ....*E. inflexa* sp. nov.

G_2 Sixth abdominal segment as long as wide; telson without movable spinules; rostrum straight, lower apical spine bent antero-inferiorly

H_1 Rostrum about half the length of carapace, the hindmost spine of upper edge situated above or slightly backward to post-orbital edge ....*E. parvula* (DE HAAN).

H_2 Rostrum two-thirds the length of carapace, the hindmost spine of upper border inserted considerably anterior to post-orbital edge ....*E. bispinosa* (DE HAAN).

Eusicyoia lancifer japonica (BALSS)

(Figs. 6, *C*; 8, *P*; 14, *A*; 22, *G*; 30, *C* and *D*; 48, *B*; 60, *A–C*; 77, *E* and *K*; 79, *H*; 151; 152; 156; *A* and *H*)

Sicyonia lancifer OL. var. *japonica*, BALSS, 1914, p. 16, fig. 9; YOKOYA, 1933, p. 11.
Sicyonia japonica PARISI, 1919, pp. 66–68, pl. 5, figs. 10, 13 and 14.

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(1) Except that of *E. parvula* (DE HAAN) and *E. bispinosa* (DE HAAN), in which it is unknown.

Rostrum reaching to or beyond distal end of second antennular segment, quadruple as long as wide measured near base, considerably recurved upwards in distal half, provided with a well-marked lateral carina on each side; armed with teeth, 3 or 4 on upper bordes, 2 or 3 on the apical, and 1 on subterminal lower edge. Carapace uneven with many longitudinal and transverse shallow depressions as exhibited in Fig. 151; hepatic region markedly swollen. Infraorbital and pterygostomian angles rounded. Hepatic spine present below second post-rostral tooth and backward to upper disto-lateral spine of basicerite. Supra-orbital, antennal and branchiostegal spines absent. Post-rostral carina remarkably developed with 6 teeth, the first lying slightly behind post-orbital margin of carapace, the third to fifth much larger in size than others, the last one inserted near posterior edge of carapace. Abdomen with one greatly developed dorso-median carina and many transverse grooves on lateral surface of anterior five segments as shown in Fig. 151; the carinae of anterior five segments posteriorly conside rablyincised, that of first segment carries a large pointed spine directed obliquely forward, those of second to fourth with a well-defined median sulcus, and that of the sixth produced into large sharply pointed tooth at posterior end. Sixth pleonic segment 0.8 times as long as wide, 0.26 times the length of carapace, not spiniform at posterior dorso-lateral angles. Abdominal pleura armed with spines; each of the anterior three has 1 at inferior end, the fourth with 1–3 (usually 3, 1 at lower end, 2 near posterior angle in typical form), and the fifth with also 1–3 (usually 2, 1 at lower, and 1 or 2 at posterior angles). Telson tapering into a point, ca. 2.7 times as long as wide measured near base, reaches a little beyond apex of inner uropod, provided with a shallow dorso-median groove, a pair of well-defined dorso-lateral carinae, and a pair of fixed dorso-lateral spines at six-sevenths, two-thirds the length of carapace, a trifle more than twice the length of sixth pleonic somite. Fifth thoracic sternite has a pair of acicular spines directed slightly antero-ventrally. Eech abdominal sternite from first to fifth armed with a stout median tooth; the tooth of first somite of male vestigial, and that of the fifth with apex directed posteriorly in both sexes.

Eyes about a fourth the length of carapace in longer diameter of cornea. Antennular peduncle half as long as carapace; intermediate joint twice the length of the last joint. Antennular flagella cylindrical, different in length upper or outer ramus thicker and longer than the other, somewhat thickened distally, three-fourths in male and two-thirds in female the length of lower ramus, about half in male and one-third in female as long as carapace; lower one simply tapering with filamentous tip. Basicerite with two disto-lateral spines, upper one of which smaller than the other. Antennal scale extending as far as antennular peduncle, 1.3 times as long as wide measured at base, narrowing anteriorly by a third, with an acute disto-lateral spine well exceeding apex of the lamella. Carpocerite reaching to far end of first antennular segment. Antennal flagella as long as body except telson.

Mandible: molar process subcircular, flattish on masticatory surface; incisor one with almost straight cutting edge; palp attains base of the last antennal joint (Fig. 14, *A*), basal segment invertedly triangular, distal one leaf-shaped with rounded spex, excavated on disto-lateral edge, with a straight longitudinal ridge on ventral surface somewhat nearer to inner edge than to the outer (Fig. 8, *P*). Maxillulary palp unsegmented, closely resembles that of *Metapenaeopsis*. First mexilliped with rather broad exopodite narrowly rounded at apex; endopodite two-jointed, basal joint lamellar, with several spinous setae on inner edge set a little nearer to tip than to base; distal one bar-shaped with rounded apex, two-thirds the length of the other; inner distal endite suboval in outline, 1.5 times as long as wide. Second seven-jointed; meropodite lamellar on inner one-third, 1.8 times the width, twice the length of dactylus. Third reaches to tip of antennal scale, strongly depressed in distal three segments, with propodus 1.5 times as long as wide and dactylus elliptical in outline, proportions in length to the last joint; ischium 1.3, merus 1.9, carpus 1.5, propodus 1.4.

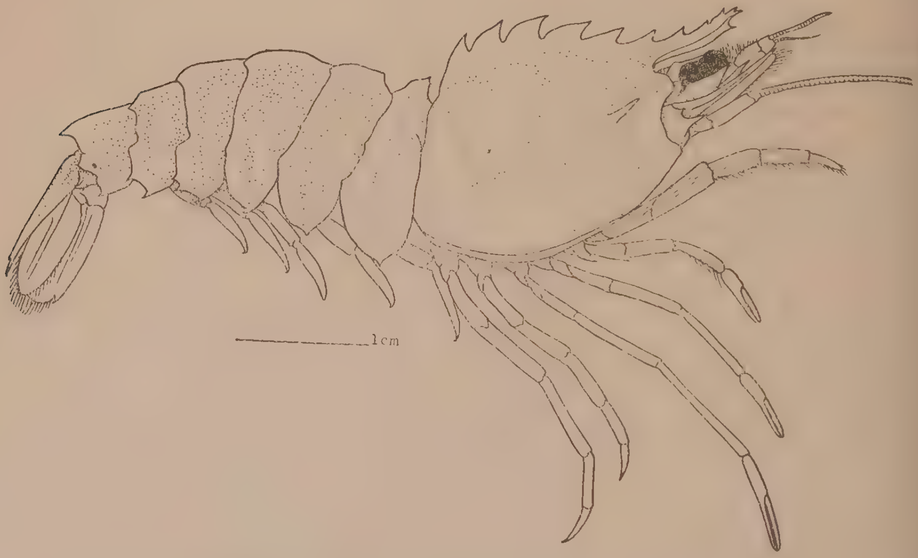

Fig. 151. *Eusicyonia lancifer japonica* (BALSS), female, 52.5 mm long (16.5 mm in carapace-length).

First pereiopod hardly reaches to tip of carpocerite, movable finger 1.23–1.55 times the length of palm. Second extending as far as antennal scale, movable finger 1.18–1.46 times as long as plam. Third surpassing tip of antennal scale by dactylus, movable finger 1.17–1.36 times the length of palm, proportions in length to movable finger: ischium 0.7, merus 1.7, carpus 2.1 (Fig. 152, *K*). Fourth stretches to base of the last antennal segment. Fifth attains distal end of antennal peduncle, proportions in length to dactylus: ischium 1.6, merus and carpus 2, propordus 1.3.

Appendix masculina unsegmented, distally thickened assuming the shape of a horse-hoof, with a tongue-like flap near outer edge of apical surface, a little shorter than endopodite (Fig. 60. *A–C*).

Petamsa considerably depressed, subrectangular in outline, twice the width, without lateral processes, armed with two pairs of pointed disto-dorsal horns (inner ones much smaller than the othar), and has a pair of ventral disto-lateral horns with abruptly pointed tip directed postero-laterally and circularly rounded anterior edge (Fig. 30, *C* and *D*).

Thelycum composed of two closely set broad plates assuming an outline of inverted T; anterior plate as long as wide with considerably concave ventral surface, suddenly narrowed into an acicular apical spine forming a rounded shoulder on each side of base of the apical spine; posterior plate thrice as wide as long, much wider than the other, with a median notch on anterior rim forming a deep subrectangular hollow with postero-lateral angles rounded (Fig. 48, *B*).

Cardiac plate carries seven equidistant spinules alined longitudinally in anterior two-thirds (Fig. 79, *H*). Cardiac ossicle subrectangular, 1.3 times as wide as long, with anterior margin somewhat convex and corners rounded (Fig. 156, *H*, *a*). Pterocardiac bar-shaped, a little arcuate with concave margin posteriorly, antero-medially produced into a point on inner edge, antero-laterally curved and abruptly narrowed with bluntly rounded apex in outer subterminal portion (Fig. 156, *H*, *b*). Prezygocardiac small, arc-shaped with narrowly rounded ends and convex margin forward. Urocardiac rather suddenly narrowed anteriorly with straight lateral edges terminating with an emarginate end, provided with a pair of large pointed processes on anterior subterminal lateral edges. Zygocardiac has two strikingly large pointed teeth besides many small ones (Fig. 79, *H*). Prepyloric with about 11 teeth on each postero-lateral edge, first 2 or 3 of which much smaller than others (Fig. 77, *E* and *K*).

Sexual differences in addition to petasma, thelycum, and appendix masculina are as follows. Hepatic spine larger in male. Sternal spine of seventh thoracic segment of male, which is homologous with anterior plate of thelycum, lanceolate with somewhat acicular distal portion, considerably narrower compered with that of female. That of first pleonic segment rudimentary in male. The last thoracic sternite of male has a pair of upstanding pillars with soft apical surface (Fig. 156, *A*). Antennular flagella of male are much longer than those of female, upper ramus about one and half times as long as that of female (Fig. 152, *B*). Endopodite of second abdominal appendage of male remains in a vestigial condition bearing a well developed appendix masculina, but that of female entirely absent.

Described from a male, 47.0 mm long (13.9 mm in carapace-length) and 12 females, 33.2–61.3 mm long (10.2–19.4 mm in carapace-length), obtained from Miya, Aichi Pref.

Distribution: Dzushi (50–100 m), Misaki (200–300 m), Fukuura, Itô (150 m), Kagoshima (150 m) (BALSS); Omae-zaki, Shizuoka Pref. (82 m) (YOKOYA).

Note: The rostral and post-rostral teeth are less variable in number: those of the upper border 3 in 12 specimens, and 4 in a specimen; those of the apical border 2 in 12 specimens, and 3 in a specimen; those of the lower border and the post-rostral carina are invariably 1 and 6 respectively.

The numbers of the pleural spines of the anterior three pleonic somites are 1 in all my specimens. Those of the fourth and fifth segments show some variation to exist, but mostly 3 in the former and 2 in the latter: those of the fourth somite is 1–3, 1 in a specimen, 2 in 3, and 3 in 8 specimens; and that of fifth one is 1 in a specimen, 2 in 11, and 3 in a spacimen.

The relative lengths of the rostrum, upper antennular flagellum of female, third maxilliped, and all the pereiopods are almost proportional to the length of carapace (Fig. 152, *A–H*). The ratios of these organs in length to carapace are as follows: rostrum 0.45–0.50, upper antennular flagellum of female 0.26–0.32, third maxilliped 1.1–1.3, first to fifth pereiopods 0.89–0.96, 1.22–1.36, 1.57–1.81, 1.05–1.30, and 1.17–1.48 respectively.

The present subspecies may be assorted from its typical form, *E. lancifer*, in the following points: (1) post-rostral spines 6 in number (4 or 5 in *E. lancifer*), (2) the last post-rostral spine considerably smaller than the penult instead of being as large as, and (3) pleural spines 2 in number in both fourth and fifth abdominal segments (3 in the typical form). But these meristic distinction appear to be variable, since at least the third character is included within a range of variation as given above. It is hoped that further investigation will decide between two alternatives whether or not the two forms are any more than geographically distinct ones,

DOFLEIN's description of *Sicyonia lancifer* (1902, p. 632), to which

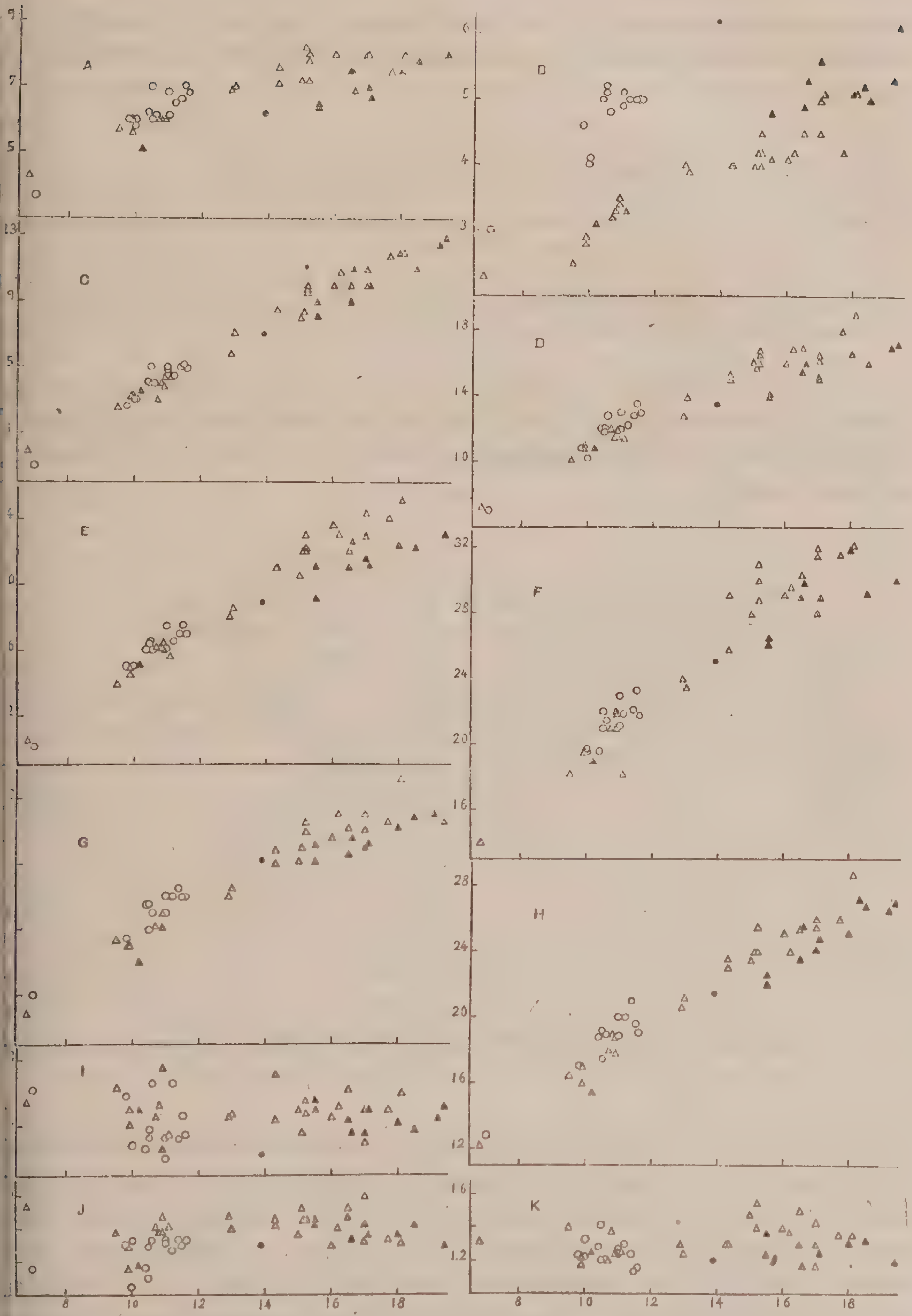

Fig. 152. Relative lengths of rostrum (*A*), upper antennular flagellum (*B*), third maxilliped (*C*), first (*D*), second (*E*), third (*F*), fourth (*G*), and fifth (*H*), pereiopods as referred to carapace; and ratios in length of movable fingers of first cheliped (*I*), second cheliped (*J*), and third one (*K*), to their palms in relation to carapace-length. Solid marks, *E. lancifer japonica*; soft ones, *E. cristata*. Circles, male; triangles, female.

the specimens collected by him from Sagami Bay was referred, is too brief to ascertain whether the specimens represent the typical form or not.

Eusicyonia cristata (DE HAAN)

(Figs. 1, *J*; 8, *L*; 10, *D*; 11, *C* and *D*; 22, *E*; 30, *A* and *B*; 48, *A*; 60, *D-F*; 76, *P* and *V*; 79, *F*; 152, *A-K*; 153; 156, *B* and *D*)

Sicyonia cristata, DE HAAN, 1850, pp. 194-195, pl. 45, fig. 10 (*Hippolyte cristatus*); STIMPSON, 1860, p. 43; RATHBUN, 1902, p. 41; BALSS, 1914, pp. 14-15, figs. 7 and 8; PARISI, 1919, p. 68; YOKOYA, 1933, p. 10.

Eusicyonia cristata is closely allied to *E. lancifer japonica* but the former is different from the latter in the annexed points on the basis o several specimens of both, measuring about 50 mm long (ca. 15 mm i carapace-length).

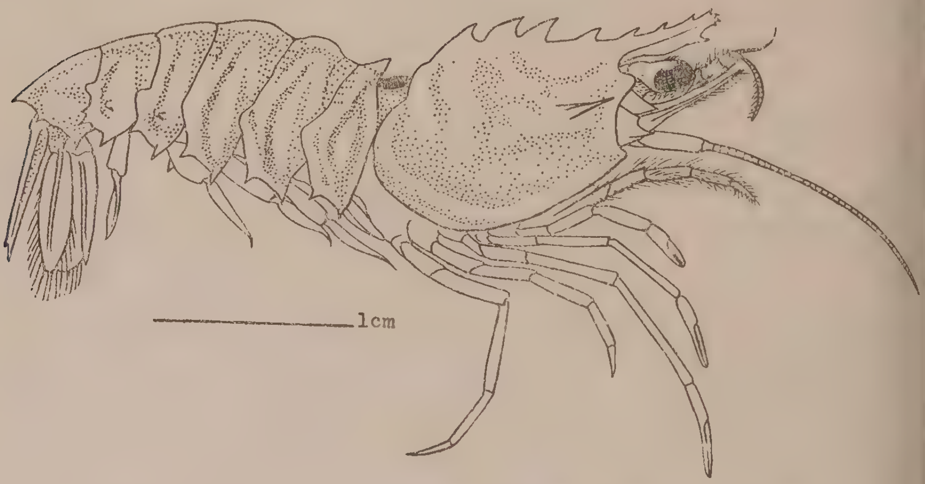

Fig. 153. *Eusicyonia cristata* (DE HAAN), male, 41.9 mm long (11.5 mm in carapace-length).

Rostrum reaches to or beyond tip of antennular peduncle, a lit more than half the length of carapace, recurved less upwards, arm with 2–4 (mostly 3) teeth on apical border; the rearmost rostral too inserted slightly anterior to post-orbital edge. Post-rostral teeth 4 number, the first set considerably posterior to post-orbital edge, th second much more distant from the first than from the third. Hepati spine laid down below about mid-way between first and second post rostral spines, hardly reaching to frontal margin of carapace, and demon strates no sexual difference. Abdomen excluding telson one and ha times the length of carapace (ca. 1.7 times in *E. lancifer japonica*) orso-median carina of first segment less incised posteriorly, with less veloped spine. Sixth pleonic segment as long as wide, 0.36 times the ngth of carapace, with spiniform dorso-lateral angle. Pleonic pleural ines much more pronounced, 1 or 2 in number in first segment, in-riably 2 in the second, 2 or 3 (mostly 3) in the third to fifth, Telson enderer, much more surmounting apex of uropods, 3.3 times as long as ide measured in the broadest region, with a pair of fixed dorso-lateral ines at five-sixths.

Eyes one-fifth the length of carapace in longer diameter of cornea. andibular palp slender, about one and half times as long as wide in stal segment (Fig. 8, *L*). Sternal plate of seventh thoracic somite of ale has a shoulder on each lateral base of apical spine as in anterior ate of thelycum (Fig. 156, *B*). Petasma: dorsal disto-median processes ncate at apex; ventral disto-lateral processes directed antero-laterally th straight anterior margin and narrowly rounded apex (Fig. 30, *A* d *B*). Thelycum: median notch of posterior plate much wider than ng (Fig. 48, *A*). Appendix masculina: tongue-like appendage lying apical surface of distal piece much thinner (Fig. 60. *D–E*).

Attention is called here to the relative lengths, as referred to cara-ce, of rostrum and all pereiodods respectively; they are somewhat aller in *E. cristata* than in *E. lancifer japonica* (Fig. 152).

A number of specimens, 14 males, 22.7–41.9 mm long (7.0–11.6 mm carapace-length) and 25 females, 22.0–57.5 mm long (6.8–18.1 mm in rapace-length) were also examined.

Locality: Suzume-zima (60 m) (Tateyama-wan), Chiba Pref.; Miya, ichi, Pref.; Kumano-nada (ca. 350 m), off Mie Pref.; Simonoseki (fish arket), Yamaguchi Pref.

Distribution: Japan (De Haan); Gulf of Kagoshima (Stimpson); ogi, Nagasaki Pref. (Rathbun); Hatsushima and Ito (150 m), Yodomi 30 m), Dzushi (0–130 m), Enoshima (80 m) (Balss); Nagasaki (Parisi); ar Tanabe (46 m), Wakayama Pref. (Yokoya).

Note: The number of spines inserted on upper and lower borders

Table 45.

	Number of Pleural spines	1	2	3
Frequency	1st segment	22	17	
	2nd "		39	
	3rd "		11	28
	4th "		6	33
	5th "		4	35

of rostrum and postrostral carina exhibit no variation so far as the present material is concerned. That of upper border is 3, that of lower border 1, and that of postrostral carina 4; but that of apical border of rostrum varies from 2 to 4 (mostly 3), viz., 2 in 1, 3 in 15, and 4 in 9 specimens.

Moreover the number of pleural spines of the first, third, fourth and fifth abdominal segments is somewhat variable, viz., 1 or 2 in the first segment, 2 or 3 (mostly 3) in the segments from third to fifth. But the spines of the second segment are invariably 2 in number (Table 45).

The longer diameter of the cornea decreases with advance of the age regardless of sex, viz., it is 0.28 times the length of carapace in specimens, ca. 22 mm long (ca. 7 mm in carapace-length), 0.22 times in specimens, ca. 35 mm long (ca. 10 mm in carapace-length), and 0.2 times in specimens, ca. 50 mm long (ca. 15 mm in carapace-length).

The proportions of the movable fingers of the first to third chelipeds in length to the palms are almost equal to those of *E. lancifer japonica* irrespective of sex and age, ranging 1.20–1.75 in the first chela, 1.05–1.59 in the second, and 1.14–1.55 in the third (Fig. 152, *I–K*).

Eusicyonia vitulans, sp. nov.

(Figs. 8, *Q*; 48, *G*; 77, *F* and *L*; 79, *I*; 154, 156, *F*)

Shell tomentous. Rostrum straight, more or less tilted upward wit straight upper and lower borders, reaching slightly beyond far end o first antennular segment, about half the length of carapace, ca. 3.5 time as long as wide measured at anterior base of second rostral tooth abruptly ends in a minute bifid tip, armed with three teeth above (th foremost inserted near tip, the intermediate at about middle, and the las somewhat anteriorly to post-orbital edge) and a tooth on ventral borde opposite the foremost upper one. Postrostral carina remarkably developed, extending to posterior rim of carapace, provided with four equidistant acute teeth directed antero-dorsally, the foremost tooth stands somewhat behind post-orbital edge, and the hindmost at three-fourths carapace. Carapace uneven with shallow grooves (Fig. 154). Infr orbital and pterygostomian angles rounded. Hepatic spine small, lyin a little in front of anterior base of second post-rostral tooth and post rior to upper edge of basicerite. Abdomen about 1.7 times the lengt of carapace, furnished with many ridges and grooves on lateral surfac and well-developed dorso-median carina, each carina of anterior fiv segments deeply incised at posterior end, that of the first produced int an acute spine directed antero-dorsally, that of the second and the thir gradually widen backward bearing a median groove, and that of th xth terminates in a sharp spine; fifth segment has a pleural spine rected backward at postero-inferior angle; sixth segment as long as de measured at middle, about a third the length of carapace, and car- es a spine at postero-inferior angle; sternal spine of second to fifth gment well-developed. Telson narrowed into a point, two-thirds the ngth of carapace, with a broad shallow dorso-median groove, a pair of ll difined dorso-lateral ridges, and a pair of fixed dorso-lateral spines ar apex, stretching as far as tip of uropods.

Eye one-fifth the length of carapace in longer diameter of cornea. ylocerite reaching a little behind distal edge of first antennular joint. cond antennular joint twice the length of the third. Antennular gella different both in size and length; upper or outer ramus thicker d somewhat longer than the other, ca. 22% the length of carapace. nsicerite bispinose, but upper spine much smaller than the other.

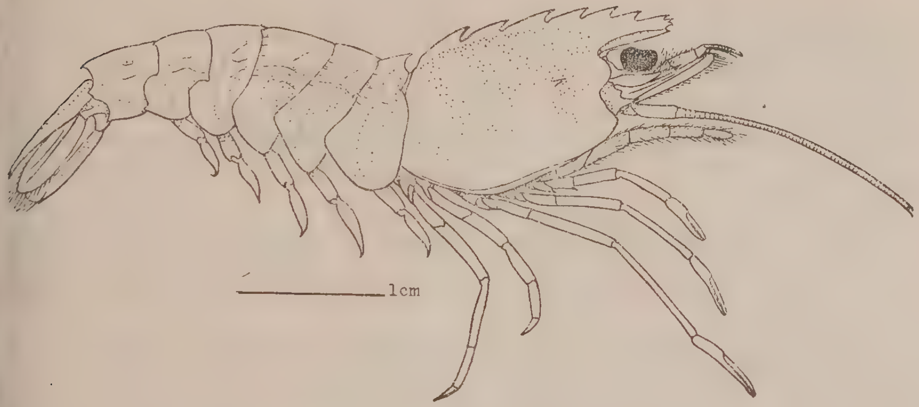

Fig. 154. *Eusicyonia vitulans*, sp. nov., female, 40 mm long (12 mm in carapace-length).

Antennal scale reaches tip of antennular peduncle, somewhat less an twice as long as wide measured at base, narrowed anteriorly by ne-third, and has a disto-lateral spine extending as far as lamella. arpocerite attains anterior end of basal antennular segment. Antennal agella about three-fifths the length of body.

Mandible: molar process flattish, ovoid on masticatory surface; ncisor one with sharp unarmed cutting edge; distal segment of palp uncate at apex, triangularly expanded on outer edge, 1.3 times as long s wide measured at the widest region, twice the length of basal segment (Fig. 8, *Q*). Maxillulary palp rather abruptly pointed at apex, ith a short spine at middle and a long spinous seta at two-thirds of nterior margin (Fig. 156, *F*). Maxilla: inner basal laciniae lacking its proximal lobe. First maxilliped resembles that of *E. lancifer japonica.* Second seven-jointed; meropodte laminar on inner one-third, 1.5 times the width, 1.6 times the length of dactylus. Third reaches far end of second antennular segment; distal five segments subequal in length.

First pereiopod extends as far as third maxilliped, movable finger 1.5 times the length of palm. Second a little surpassing tip of antennal scale. Third stretching beyond tip of the scale by chela, proportion in length to movable finger: inschium 1, merus 1.8, carpus 2.4, palm 0.8. Fourth attains pterygostomian angle. The last reaching tip of antennal peduncle, proportions in length to dactylus: ischium 1.7, merus and carpus 2.8, propodus 1.8.

Thelycum made up of two closely set plates; anterior plate assumes the outline of violin with an acicular spine at apex; posterior one twice wider than the other, and carries an auriculate lobe on each side (Fig. 48, *G*).

Cardiac plate with 11 spinules (Fig. 79, *I*). Cardiac, pterocardiac, prezygocardiac, and urocardiac ossicles similar to those of *E. lancifer japonica.* Zygocardiac has two large sharply pointed pyramidal teeth on anterior margin, upper one of which followed by two vestigial teeth ventral edge provided with 9 or 10 rather sparsely set slender pointe teeth in posterior half (Fig, 79, *I*). Prepyloric has 7 teeth besides accessory ones on each postero-lateral edge (Fig. 77, *F* and *L*).

Type: a female, 40 mm long (12 mm in carapace-length).

Locality: Kumanonada (ca. 350 m), off Owase, Mie Pref. (collecte by Mr. G. ABE).

The present species is near to *Eusicyonia critata* (DE HAAN), bu easily recognizable from the latter in the possession of shorter rostrum more elevated postrostral carina, much smaller hepatic spine, unarme anterior four abdominal pleura, less armed fifth pleonic pleura, and diag nostic anterior plate of thelycum.

Eusicyonia curvirostris (BALSS)

(Figs. 8, *K*, 30, *E* and *F*; 48, *E*; 60, *G–I*; 77, *D* and *J*; 79, *L*; 155, 156, *C*).

Sicyonia curvirostris, BALSS, 1914, p. 17, fig. 10; YOKOYA, 1933, pp. 11–12, fig. 3, *A–D*.

Male; rostrum large, uptilted at an angle of ca. 35°, curved forwar in distal one-third, reaching slightly beyond far end of first antennul segment, 2.3 times as long as wide measured near base, armed wit teeth, 3 on dorsal border (the last one set somewhat anterior to pos orbital edge), 2 on apical border, 1 at four-fifths of the lower border.

Carapace with rather macked post-ocular and hepatic grooves (Fi 155). Post-rostral carina sharply defined, extending to posterior margi of carapace, furnished with three teeth, the first tooth stands somewha ehind post-orbital edge, the second about at a third of carapace, and e third at two-thirds. Hepatic spine moderate in size, situated below iddle between first and second post-rostral spines and posterior to upper dge of basicerite. Abdomen ornamented with many ridges and grooves n lateral surface; dorso-median carina of each segments well-developed, hat of first four segments gradually widen backward and incised posteiorly with well-marked dorso-median groove, that of the first has acute pine directed antero-dorsally, and that of the sixth terminated in a harp spine. Abdominal pleura of first five segments rounded on lower argin, that of the fifth and sixth has each a minute spine directed ackward at postero-inferior angle. Sixth pleonic segment as long as ide, a trifle less than half the length of carapace. Telson resembles hat of *E. lancifer japonica*, with a pair of fixed dorso-lateral spines

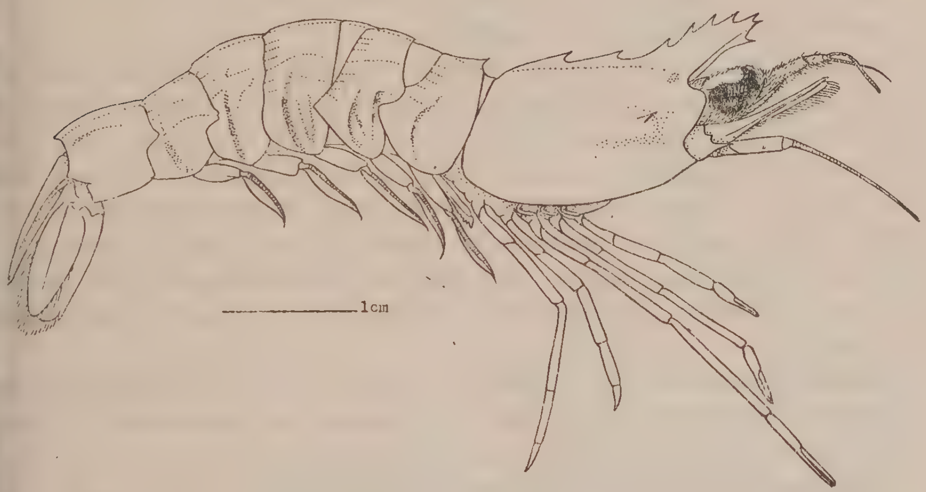

Fig. 155. *Eusicyonia curvirostris* (BALSS), male, 57.4 mm long, lacking third maxillipeds.

ear apex, somewhat surpassing apexes of uropods, 0.8 times the length f carapace. Sternal spine of seventh thoracic somite very similar to hat of *E. lancifer japonica* in shape, though somewhat slenderer. The ast thoracic sternite has a pair of tufts of hairs (Fig. 156, *C*).

Eye about 3/10 times as long as carapace in longer diameter of ornea. Stylocerite distally recurved upward, reaching to anterior border of basal antennular segment. Second antennular segment twice the ength of the third.

Antennular flagella different in length and size; inner ramus shorter and thiner than the other which is about half the length of carapace. Basicerite bispinose, but upper spine much smaller than the lower.

Antennal scale attains tip of antennular peduncle, twice as long as wide measured at base, distally decreasing in width by two-fifths, having a disto-lateral spine which well surmounts apex of lamella. Carpocerite stretches as far as first antennular joint, thrice the width. Antennal flagella somewhat less than half the length of body. Mandible: molar process ovoid, flattish on masticatory surface; incisor one with unarmed cutting edge; palp similar to that of *E vitulans* (Fig. 8, *K*). Second maxilliped pediform; merus 1.5 times the width, 1.9 times the length of dactylus.

First pereiopod reaching apex of carpocerite. Second attains far end of second antennular segment, movable finger somewhat (ca. 3/10) longer than palm. Third extending beyond tip of antennular peduncle by fingers, proportions in length to dactylus: ischium 1.1, merus 1.9, carpus 2.5, propodus 0.9. Fourth reaches to far end of basicerite. Fifth stretching as far as eye, proportions in length to the last joint: ischium 1.5, merus 2.3, carpus 2.8, propodus 1.7.

Petasma has a pair of large pointed transverse projections directed at right angles; dorsal distal margin with two pairs of short processes directed anteriorly, the inner ones slightly convex on distal edge, and the outer sharply pointed; each ventral disto-lateral angle bears a pair of short spines, anterior one of which recurved backward with semicircularly rounded anterior margin, the other thin with pointed tip directed ontwards, a little longer than the anterior; each ventral disto-median angle has a process with narrowly rounded apex directed forward (Fig 30, *E* and *F*).

Apendix masculina very similar to that of *E. lancifer japonica* and *E. cristata* in general feature, but the tongue-like appendage of apical surface attached to the center (Fig. 60, *G–I*).

Cardiac plate with 12–14 spinules in anterior two-thirds, and zygocardiac ossicle resembles that of *E. vitulans* (Fig. 79, *L*). Urocardiac broadly rounded on anterior rim, with a pair of large pointed processes on lateral margins near anterior end. Prepyloric has about 9 pointed teeth (2 or 3 proximal ones minute) on each postero-lateral edge (Fig 77, *D* and *J*).

Female: antennular flagella shorter than those of male, 0.23 times in inner and 0.3 times in outer rami the length of carapace. Third maxilliped reaching tip of antennal scale, proportions in length to dactylus: ischium and propodus 1.5, merus 2, and carpus 1.8.

Thelycum made up of two closely set plates; anterior plate assuming the outline of an inverted funnel with a long acute apical spine and a notch on either lateral edge near base; the other twice wider than long, much broader than anterior plate, with more or less convex lateral edges, and has a large median notch on anterior border forming eep rectangular hollow which is narrowed posteriorly by half, twice as ng as wide measured along posterior border (Fig. 48, *E*).

The description and figures given above are based on a male, 57.4 m long (14.3 mm in carapace-length), which is mutilated of third maxilpeds, and a female, 58.5 mm long (15 mm in carapace-length). Other 3 males, 42.3–56.2 mm long (11.4–16.2 mm in carapace-length) were also xamined.

Locality: Kumanonada (ca. 350 m), off Daiô-zaki, Mie Pref. (G. BE); off Mimase, Kochi Pref. (J. ISHIKAWA).

Distribution: Fukuura, Sagami Bay (150 m) (BALSS); South of himoda, Shizuoka Pref. to Sata-Misaki, Kagoshima Pref. (77–219 m); ear Gotô Is., Nagasaki Pref. (194–219 m) (YOKOYA).

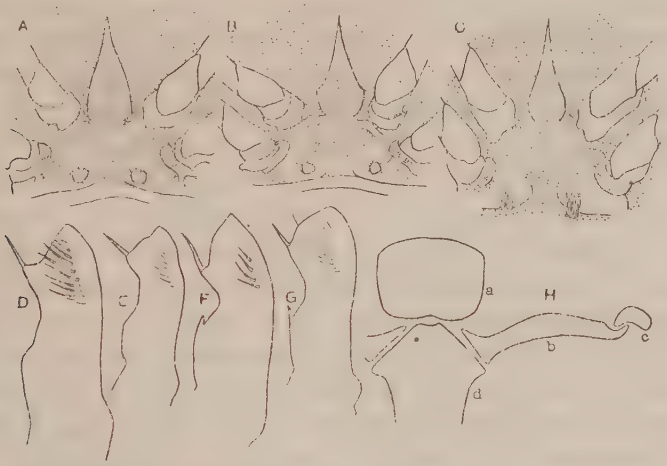

Fig. 156. Sternal projection of penult thoracic sternite and genital sternite of male (*A–C*); maxillulary palp (*D–G*); and cardiac (*a*), pterocardiac (*b*), prezygocardiac (*c*) and anterior about half of urocardiac (*d*) ossicles (*H*). *A* and *H*, *Eusicyonia lancifer japonica*, 45 mm long (15 mm in carapace-length); *B* and *D*, *E. cristata*, 43 mm long (12 mm); *C*, *E. curvirostris*, 58.5 mm long (15 mm in carapace-length); *E*, *E. truncata* sp. nov.; *F*. *E. vitulans*, sp. nov.; *G*, *E. nebulosa*, sp. nov. *A* and *B*, ×2.5; *C*, ×3; *D* and *E*, ×20; *F*, ×25; *G*, ×35; *H*, ×12.5.

Note: Two types may be recognized in the feature of the rostrum, iz., one with a spine on the apical border as represented in the figure iven by BALSS and YOKOYA, and the other bispinose as given in Fig. 55. Off five specimens under examination, the former type is found in , and the latter in other 3.

It is worth noting that the eyes of the smallest specimen (female, 2.3 mm long) is found comparatively smaller than those of others: the onger diameter of the cornea is one-fourth the length of carapace.

The specimens at the writer's disposal well agree with the description and illustration given by BALSS (*loc. cit.*), and tally with those of YOKOYA (*loc. cit.*). But the following respects were overlooked by YOKOYA, viz., the dorso-median spine of the first abdominal segment, the posterior disto-lateral spines of ventral lobule of the lateral lobe of the petasma, the arthrobranchia of the third thoracic somite and the vestigial one of the seventh, the podobranchia of the second, and the mastigobranchia of the second.

Eusicyonia nebulosa sp. nov.

(Figs. 8, *N*; 48, *C*; 77, *B* and *H*; 79, *K*; 156, *G*; 157).

Shell pubesent. Rostrum straight, inclined upward at an angle of ca. 30°, extending as far as first antennular segment, about one-third the length of carapace, somewhat narrowed anteriorly, thrice as long as wide measured at anterior base of the rearmost rostral spine; upper border turning horizontally in subterminal portion; lower border almost straight, furnished with lateral ridge near ventral border, armed with seven teeth, anterior two of which are minute, and the hindmost one located a little behind post-orbital edge (Fig. 157). Post-rostral carina sharply defined and reaches to posterior rim of carapace, furnished with two teeth, anterior one set at a fourth and the posterior one at middle of the carina. Hepatic spine lying below first post-rostral tooth and backward to upper edge of basicerite. Abdomen dorsally carinated; the carina of first two segments have an acute spine at anterior end, that of first four segments grooved dorsally and incised posteriorly, and that of the sixth ends in a spine; sixth segment 1.3 times as long as wide measured at middle, about half the length of carapace; all pleura rounded on inferior margin except that of sixth somite, which is straight on lower edge and has a spinule at posterior end. Telson with a shallow dorsomedian furrow, a dorso-lateral carina on each side, and a pair of fixed subterminal spines, considerably surpassing apexes of uropods which are subequal in length, ca 1.4 times the length of sixth pleonic segment.

Eyes about a quarter the length of carapace in longer diameter of cornea. Stylocerite attains distal end of eye. Antennular stalk extending as far as antennal scale, intermediate joint twice as long as the last. Antennular flagella different in length and size; outer ramus thicker and longer than the inner, a trifle less than one-fourth the length of carapace. Basicerite with a disto-lateral spine. Antennal scale similar to that of *E. curvirostris* but the disto-lateral spine extending as far as lamella. Carpocerite reaches to midway of the scale, quardruple the width.

Mandible: molar process elliptical, somewhat indent on masticatory urface; incisor one unarmed on cutting ebge; palp comparatively slender, basal joint twice as long as wide, distal one pentagonal in outline vith truncate apex and triangularly produced outer rim, 1.5 times the vidth measured in the broadest region, 1.3 times the length of the outer Fig. 8, *N*). Maxillulary paly rather slender, rounded on apex, with two pinous setae on anterior margin as in *E. vitulans* (Fig. 156, *G*). Maxila, and first maxilliped closely resemble those of *E. lancifer japonica.* Second maxilliped typical in shape; merus lamella on inner side, 1.9 imes the width, 2.2 times the length of the last article. Third slightly urpassing distal end of first antennular segment, propotion in length to lactylus: ischium 1.7, merus 1.9, carpus 1.6, propodus 1.4.

First pereiopod reaching to middle of carpocerite. Second attains ip of antennular peduncle; palm and movable finger subequal in length.

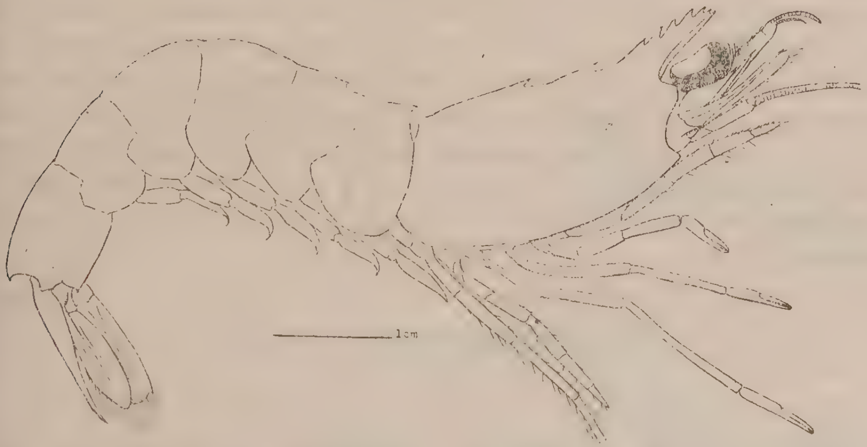

Fig. 157. ***Eusicyonia nebulosa,*** sp. nov., female, 27 mm long (8 mm in carapace-length).

Third surmounts tip of antennular peduncle by half of chela, proportions in length to movable finger: ischium 1.5, merus 2, carpus 3.5 palm 1. Fourth reaches to a third of carpus of third limb.

Thelycum composed of two flattened closely set plates; anterior plate ogival in outline with an acicular apical spine, notched at basal a quarter of each lateral edge, rounded at postero-lateral angles, 2.5 times as long as wide measured in the widest region; basal plate much wider than long and much wider than the other, and has anteriorly an ovoid small median hollow (Fig. 48, *C*).

Cardiac plate bears 6 or 7 spinules in anterior half. Cardiac, pterocardiac and prezygocardiac ossicles similar to those of *E. lancifer japonica.* Urocardiac tallies with that of *E. curvirostris.* Zygocardiac furnished with two large and many accessory acute teeth (Fig. 79, *K*).

Prepyloric with about 9 pointed teeth along each postero-latera edge, the teeth become gradually larger in size toward tips (Fig. 77, and *H*).

The above mentioned description and figures are based on a femal 27 mm long (8 mm in carapace-length), lacking distal portion of antenna flagella and last two segments of fifth pereiopods. Besides a simila sized female without antennal flagella, third and fifth periopods, was als examined. Both specimens secured off Heta (ca. 350 m), Shizuoka Pref

Note: The species newly erected here is very intimately related t *E. fallax* (DE MAN)⁽¹⁾ from Sulu Sea. But it may be recognized fro the latter on basis of the following features: rostrum less uptilted (ca 45° in *E. fallax*), with almost straight lower border, and without a toot just below apex; the last post-rostral tooth located a little posterior t middle of carapace (at ca. a third in *E. fallax*); second pleonic segme has a spinule at anterior end of its dorso-median carina; sixth pleoni somite 1.3 times as long as wide instead of being somewhat more tha one and half; telson considerably surpassing tips of uropods, secon antennular segment twice the length of the last; third maxilliped reac ing to far end of basal antennular segment; third pereiopod surmounti tip of antennal scale by half of chela, carpus 1.7 times the length chela, palm and finger subequal in length; anterior plate of thelycu relatively wider.

Eusicyonia truncata, sp. nov.

(Figs. 8, *M*; 48, *F*; 77, *A* and *G*; 79, *J*; 156, *E*; 158)

Body tomentous. Rostrum subrectangular in profile, directed upwa at an angle of about 30°, extends a little beyond distal end of first antennular segment, 2/5 of carapace-length, about 2.5 times as long as wid with lateral carina near ventral border, intervals between the tee become gradually smaller toward apex, the rearmost tooth situate slightly backward to post-orbital edge, the foremost one minute, insert at end of upper border) and 1 at dist-ventral angle, directed forwar (Fig. 158). Post-rostral carina sharply defined, reaching to posteri margin of carapace, bears two teeth the anterior one set at a third carapace and the other at two-fifths. Hepatic spine set mors or le anterior to first post-rostral tooth and posterior to upper edge of basic rite. Abdormen dorsally carinated as in *E. nebulosa;* each of the cari of first two segments has an acute spine at its anterior extremity, th of the sixth ends in a sharp spine directed backward; pleura of fir five segments rounded on inferior border, that of the fifth armed with

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(1) DE MAN, 1911, pp. 115–116. Pl. 9. fig. 38 (1913).

spine projocting backward at postero-inferior angle, that of the sixth slightly convex with a minute spine at posterior end; sixth segment 1.5 times as long as wide, half as long as carapace. Telson very similar to that of *E. nebulosa*, a little exceding tip of uropods which are subequal in length, measuring about 7/10 of carapace.

Eyes a quarter the length of carapace in longer diameter of cornea. Stylocerite extending somewhat beyond eye. Antennular peduncle two-thirds as long as carapace, intermediate joint thrice the length of the last. Antennular flagella subequal in length, upper ramus a little thicker than the lower, about a quarter of carapace in length. Basicerite has an acuminate disto-lateral spine. Antennal scale stretches as far as antennular peduncle, a quarter times as long as wide, narrowed anteriorly by a third, armed with a disto-lateral spine well exceeding apex of lamella. Carpocerite reaches to distal margin of eye. Antennal flagella more or less longer than carapace.

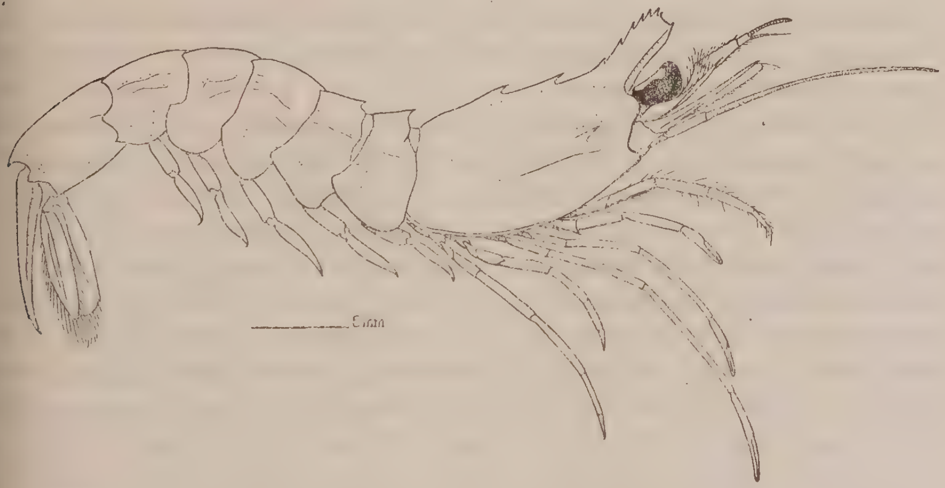

Fig. 158. *Eusicyonia truncata*, sp. nov., female, 44 mm long (12 mm in carapace-length).

Mandible: molar process flattish, elliptical on masticatory surface. Incisor one unarmed; palp near to that of *E. nebulosa*, distal segment with broadly rounded apex, 1.3 times the width in the broadest region (Fig. 8, *M*). Maxillulary palp rather slender, wavy on both anterior and posterior borders, narrowly rounded at apex, and has a spinous seta at distomedian angle (Fis. 156, *E*). Maxillary palp with a short protuberance at distal inner angle. First and second maxillipeds typical in shape, meropodite of the latter laminar on inner half, 1.6 times the width, twice the length of dactylus. Outer maxilliped stretches to distal edge of second antennular segment, proportions in length to the last joint: ischium 1.2, merus, carpus and propodus 1.8.

First pereiopod surmounts basicerite by finger. Second attains tip of antennular stalk. Third reaching beyond tip of antennuler stalk by half of chela, propotions in length to movable finfier: ischium 1, merus 2.1, carpus 3, palm 1.1. Fourth attains pterygostomian angle. The last exceeding basicerite by dactylus, proportions in length to dactylus: ischium 1.2, merus 2.6, carpus 2.9, propodus 1.8.

Thelycum made up of two closely set flat plates; anterior plate assumes the outline of inverted funnel with sharply pointed long apical spine as in that of *E. curvirostris*, though without a notch on each lateral rim; posterior plate devoid of median hollow (Fig. 48, *F*).

Cardiac plate has 4 spinules. Cardiac, pterocardiac, prezygocardiac, and urocardiac ossicles similar to those of *E. lancifer japonica*. Zygocardiac naer to that of *E. curvirostris* (Fig. 79, *J*). Prepyloric carries 7 conical teeth on each postero-lateral edge (Fig. 77, *A* and *G*).

Holotype: a female, 44 mm long (12 mm in carapace-length).

Paratype: a female, 43 mm long (11.5 mm in carapace-length).

Locality: Kumanonada (ca. 350 m) off Owase, Mie Pref. (Type); off Kôchi, Shikoku (J. Ishikawa).

The present species is closely related to *E. bispinosa* (De Haan),(1) but easily separable from the latter by having the annexed characters rostrum shorter (slightly surpassing basal antennular segment, two-fifth the length of carapace) and broader (2.5 times as long as wide), with teeth above, devoid of spines on apical border except those lying a disto-ventral corners (reaching to far end of second antennular segment two-thirds the length of carapace, 6 times as long as wide, with 4 teeth above and 2 ones on apex in *E. bispinosa*); second abdominal somit with a spine at anterior end of its dorso-median carina; intermediat joint of antennular peduncle about thrice as long as the last.

Eusicyonia inflexa sp. nov.

(Figs. 8, *O*; 48, *D*; 77, *C* and *I*; 79, *G*; 159, 160, *A–F*)

Rostrum variable in length and shape as given later, but alway uptilted at an angle of about 30°. Post-rostral carina sharply defined, extending to posterior edge of carapace, with two teeth, anterior one o which laid down at a third, and the posterior larger one at two-thirds. Hepatic spine well developed, inserted somewhat anterior to first post-

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(1) De Haan, 1850, p. 195, pl. 45, fig. 9; De Man, 1911, pp. 120–121, pl. 10, figs. 42 and 42 a–c (1913).

rostral tooth and posterior to upper edge of basicerite. Abdomen except telson 1.8 times the length of carapace, strongly carinated along dorso-median line; the carina of first five segments deeply incised posteriorly, that of the first raised into a large acute tooth directed obliquely forwards, that of the second and third much wider than others with a median sulcus, and that of the sixth forms an acuminate tooth directed backward at posterior extremity. Sixth abdominal segment 1.5 times the width measured at middle, 1.7 times the length of the fifth. Pleonic lateral walls ornamented with ridges and grooves as follows; a longitudinal ridge runs at middle in segments first to sixth, that of the first defined in intermediate a third only, that of the fourth less marked and posteriorly interrupted by a transverse groove, that of the sixth vanishing in posterior third, and that of the second to the fourth a little inferiorly associated with a similar one which extends to about middle in the second and the third, as ill-defined as upper one and reaching to posterior transverse groove in the fourth; an arcuate transverse groove lies somewhat nearer to posterior edge than to anterior one in the first to fifth; a leaf-shaped transverse swelling exists in front of the transverse groove in the second to the fifth, that of the latter two rather marked anteriorly (Fig. 159). Telson with acute tip, slightly surpassing apexes of inner uropods which are a trifle longer than the outer, measuring about 60% of carapace-length; provided with a shallow dorso-median furrow and a pair of sharply defined dorso-lateral edges, and has a pair of fixed dorso-lateral spines besides two series of movable ones; a series consists of about 15 pairs of microscopic stout spinules placed along inner base of each dorso-lateral ridge in distal two-thirds; the other made up of three spinules a little larger than theos of the former, set along each lateral margin of telson in distal third as is the case with *E. longicauda*, from south Africa (STEBBING, *op. cit.*).

Eyes a quarter the length of carapace in longer diameter of cornea. Stylocerite extends well beyond apex of eyes. Antennular peduncle two-thirds as long as carapace; basal joint furnished with an acicular disto-lateral spine; second joint three and half times the length of the last. Antennular flagella different in length and size; upper (or outer) ramus thicker and longer than the other, measuring about 25% of carapace-length. Basicerite unispinose. Antennal scale subrectangular, a quarter times as long as wide measured at base, narrowed anteriorly by half, with a disto-lateral spine much exceeding apex of lamella. Antennal flagella about half the length of body.

Mandible: molar process lunate, flattish on masticatory surface. Incisor one unarmed. Palp extending to base of the last antennal segment; distal segment pentagonal in outline with truncate apex and triangularly expanded outer edge, 1.4 times as long as wide measured in the broadest region (Fig. 8, *O*). Second maxilliped inverted J-shaped meropodite lamellar in inner half, 1.8 times the width, 2.1 times th length of the last joint. Third maxilliped reaching to anterior end o second antennular segment; merus, carpus, propodus subequal in length and somewhat longer than dactylus.

First pereiopod slightly surpassing antennal stalk, movable finger more or less longer than palm. Second stretching as far as third maxilliped, carpus 1.6 times the length of chela with palm and finger almost equal in length. Third surmaunts tip of antennular peduncle by about two-thirds of chela, proportions in length to movable finger, ischium 2 merus 3, capus 4, palm 1.3. Fourth extending beyond pterygostomian angle by about dactylus. Fifth attains tip of antennal peduncle, proportions in length to dactylus, ischium 1.6, merus 3, carpus 3.5, propodus 1.9.

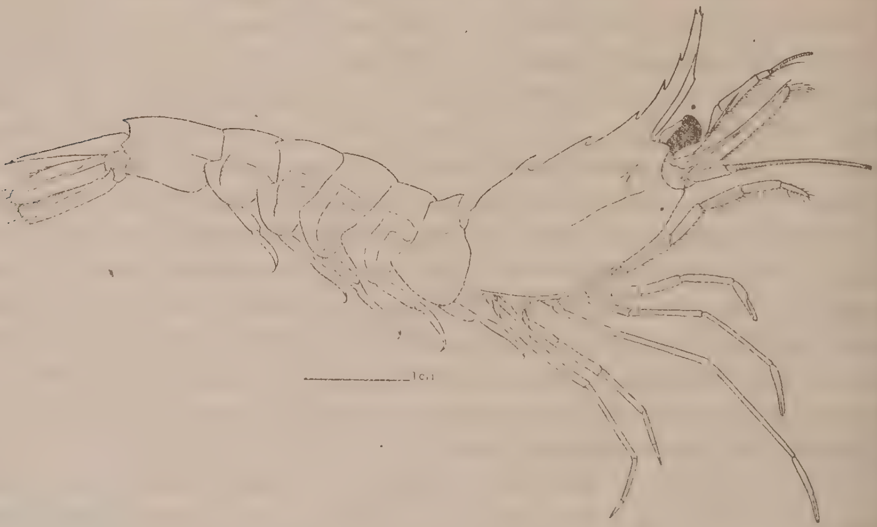

Fig. 159. *Eusicyonia inflexa*, sp. nov., female, 62 mm long (18 mm in carapace-length).

Pleonic sternal spines short, conical, directed antero-ventrally.

Thelycum made up of two plates: anterior plate lanceolate wit acicular apex reaching to base of second pereiopods, proximally notche on lateral edges, with flat concave ventral surface; posterior one abou twice wider than long, much wider than the other, with straight anterio margin running antero-laterally in each half and with considerably convex lateral margins, angulated at antero-lateral corners, anteriorly provided with a with a median notch which forms a hollow assuming th outline of arrow-head (Fig. 48, *D*).

Cardiac plate with 5–8 spinules. Urocardiac ossicle triangularly ilated at anterior end with rather broadly rounded apex and narrowly unded lateral corners. Zygocardiac has two large teeth on anterior dge, upper one of which followed by two accessory ones; ventral bor- er armed with anteriorly two rather large and posteriorly about 7 ender teeth (Fig. 79, *G*). Prepyloric bearing 7–9 sharply pointed slen- er teeth on each postero-lateral edge (Fig. 77, *C* and *I*). Other ossicles losely resemble those of *E. lancifer japonica.*

The material dealt weth is represented by 8 females only, measuring 7.5–62 mm long (10.5–18.0 mm in carapace-length). The description and gures given above are based on the largest specimen.

Locality: Off Atsumi, Aichi Pref. (ca. 300 m); Kumanonada (ca. 00 m), off Owase, Mie Pref.

Note: The rostrum displays remarkable variations in shape, length, nd dentation irrespective of size of body. It is a little recurved in ubterminal portion in six specimens out of eight ones, almost straight the rest. The length is 55–72% of the carapace-length. The apical order is obliquely truncate in most cases. The spines beset on the pper border are invariably three in number, the rearmost one stands bove, or somewhat in front of, the post-orbital edge, and those of the pical border are two or three in number (Fig. 160).

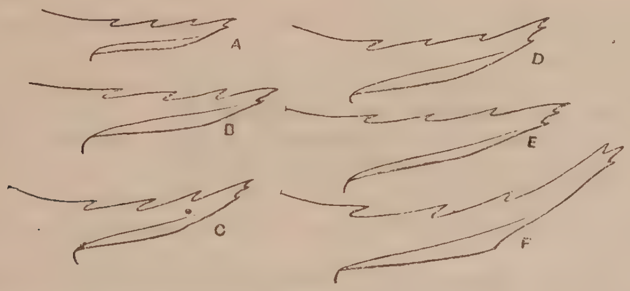

Fig. 160. Showing rostral variation of *E. inflexa,* sp. nov. Each figure magnified 3.5 times. Numerals representing body-length and carapace-length in mm, the latter given in brackets. *A*, 37.5 (10.5); *B*, 46 (13.6); *C*, 47 (13.8); *D*, 57 (15.1); *E*, 57 (16.5); *F*, 62 (18).

Remarkably enough, the largest specimen greatly deviates from thers in shape of rostrum and relative length of the antennal peduncle. s represented in Figs. 159 and 160, *F*, the rostrum is very long, emarkably upcurved in distal half, with a prong at half-way of the wer margin (a less defined condition is found in another specimen, ig. 160, *C*), and vertically trancate apex with a median spine much rger than those lying above and below it. The antennal peduncle extends to about a third of the antennal scale instead of reaching to about middle of the scale.

The present species strikingly resembles *Eusicyonia longicauda* (RATHBUN) (RATHBUN, and STEBBING, *op. cit.*) from deep-seas of Hawaiian Islands and South Africa, however, it may be discriminated from the latter in possession of the following characteristics: rostrum reaches to at least tip of antennular peduncle, distally recurved upwards in most cases; sixth abdominal segment one and half times as long as wide measured at middle, 1.7 times the length of fifth abdominal one (twice as long as wide, according to the figure, and also twice the length of fifth pleonic segment in *E. longicauda*); telson has about 15 pairs of mobile spinules along inner side of each dorso-lateral carina; and anterior plate of thelycum with a pair of notches on lateral edges near base (entire, according to STEBBING, in *E. longicauda*).

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INVESTIGATIONS

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第三十六卷　第二冊

ビタミンCのポーラログラフ的研究

岡田郁之助

Polarographic Studies on Vitamin C

(With English Résumè)

東京水產大學
橫須賀市久里濱

昭和二十五年二月

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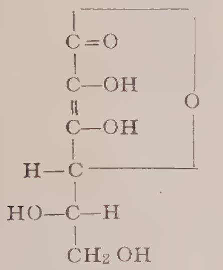
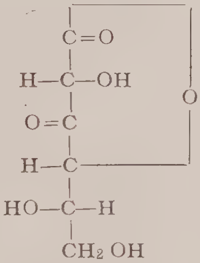
ビタミンCのポーラログラフ的研究

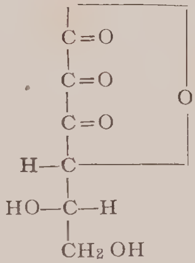
緒　　言

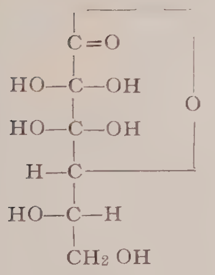
ビタミンC即l-アスコルビン酸の構造式はⅠ式の如くであり、又そのケト型（Ⅱ）としても存在し得る、而して之は還元性甚だ強く色々のものを還元し、自身は容易に酸化して可逆酸化型 Dehydroascorbic acid（Ⅲ又はⅣ）を生ずる。このものは抗壊血病性を有して居り、ビタミンCとしての作用も還元型と同様である。

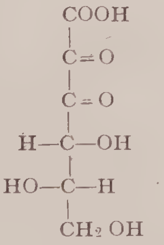
可逆酸化型は組織により容易に還元されて原型に復す、かゝる酸化還元機序により水素傳達体として細胞呼吸に関與し得るものと考えられている。この可逆的性質はビタミンCの特殊性であつてその生理作用の基調をなすもである。l アスコルビン酸は更に酸化されると不可逆酸化型（Ⅴ）となり抗壊血病性を失う。此者は酸化すると遂には l-Threon酸（Ⅵ）及び蓚酸（Ⅶ）を生ずるに至るものである。

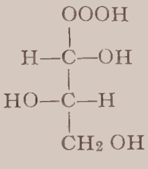

（Ⅰ）
l-Ascorbin酸

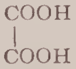

（Ⅱ）
（Ⅰ）のketo型


（Ⅲ）
Dehydroascorbin酸
（可逆酸化型）


（Ⅳ）
（Ⅲ）の水加物


（Ⅴ）
2.3-Diketo-l-gulon酸
（不可逆酸化型）


（Ⅵ）
l-Threon酸


（Ⅶ）
蓚　酸

以上の如くビタミンCは生物学的に重要であるので京都大学教授舘先生の御指導の下にポーラログラフを應用して正確なる定量法を行つて見たのである。

更に前述の如くビタミン C は相当に不安定な物質であるので之が安定化の重要性のためポーラログラフによるビタミン C の安定化に関し種々の酸類及び塩類を用いてビタミン C の安定化に関する研究を行つた次第である。

第1章

ビタミンCの定量

アスコルビン酸の定量法として之迄報告された主なるものは次の如くである。

（1） インドフエノール法

2−6 Dichlorphenol-Indophenol を用い之をアスコルビン酸により還元褪色せしめ、その褪色による滴定量よりアスコルビン酸量を求めるもの（Tillmans(1)，Harris(2)，Bessay,(3)；藤田、岩竹(4)）

（2） メチレン青法

アスコルビン酸を照射するとメチレン青を短時間内に褪色せしめる作用を利用する。（Martini(5)， Neuweiler(6)， Wachholder(7)）

（3） Bezssonoff 法

Monomobybdo-phospho-wolfram 酸がアスコルビン酸によつて還元されて紫色を呈する反應を利用したもの（Bezssonoff(8)）

（4） Folin 試薬を用いる法

Phospho-18-wolfam 酸がアスコルビン酸によりて還元されて青色を呈する反應を利用するもの（Laporta(9)， 山本(10)， Wachholder(11)， 藤田，海老原(12)）

（5） フエリチアン加里法

フエリチアン加里を酸性に於てアスコルビン酸で還元して出來たフエロチアン加里を伯林青反應で定量するもの（Tauber(13)）

以上のうち（1）は之まで最も廣く用いられ現在に於ても可なり行われている。（2）は欧米に於て殊に臨床家の間に於て一部には好んで行われている。之はインドフエノール法に比して往々小なる値を與えるのでより特殊性であるというのであるが、之は甚だ不確実なる方法であつて且つ必ずしもインドフエノール法よりも小なる値を與えないとの事であり、此の方法の信頼し難き所以は既に藤田氏(14) により実証されている。（3）及び（5）はインドフエノール法よりも通常多く出るから特殊性は之に劣ると云うべく（4）に於ける方法は呈色液の美麗にして持久性なる点に於て優れているが、ビタミン C 以外の物質の影響を充分に避け難い欠点があるが藤田、海老原氏(15) 法による時は充分酸性に於て作用せしめ且つ沃度醋酸を用いて硫水基を有する物質の

影響を皆無たらしめ、ビタミン C 定量法として特殊性にして且つ優れたる方法である。而してインドフエノール法としては藤川、岩竹氏(16) 法による時最も眞ビタミン C 價に近く且つ確実であり、適当な注意を拂えばビタミン C 定量法として多くの場合信頼し得るものである。

ビタミン C 定量法として従來上述の如き各種の方法があるが著者(17) はポーラログラフを應用してビタミン C の定量を簡單に且つ正確に行う事が出來た。

ビタミン C のポーラログラフ的研究に関しては E. Kodicek氏(18) が行つている。同氏の方法はアスコルビン酸を燐酸緩衝液（pH＝7.0）に溶かし、水銀滴下電極を陽極とする場合にビタミン C のポーラログラムが得られたと報告している。而してビタミン C のポーラログラフ法による定量に関しては研究を行つていない。著者は同氏の方法を追試して見たが結果は不定であつて一定のポーラログラムは得られなかつた。それで硫酸水銀の陽極を用い E. Kodicek氏(18) の如く極を反対とせず水銀滴下電極を陰極となし pH 7.0 の燐酸緩衝液にアスコルビン酸を溶かし実験を試みた処好結果が得られ、尚之に枸櫞酸を少量加える事によつて一定のポーラログラムが得られ定量的に應用する事が出來、一度アスコルビン酸の標準ポーラログラムを撮つて置けば非常に簡單に短時間にビタミン C の定量が出來、ビタミン C 以外の還元性物質の存在する場合でもポーラログラフ法による時は眞のビタミン C の定量が出來るものと考えられる。

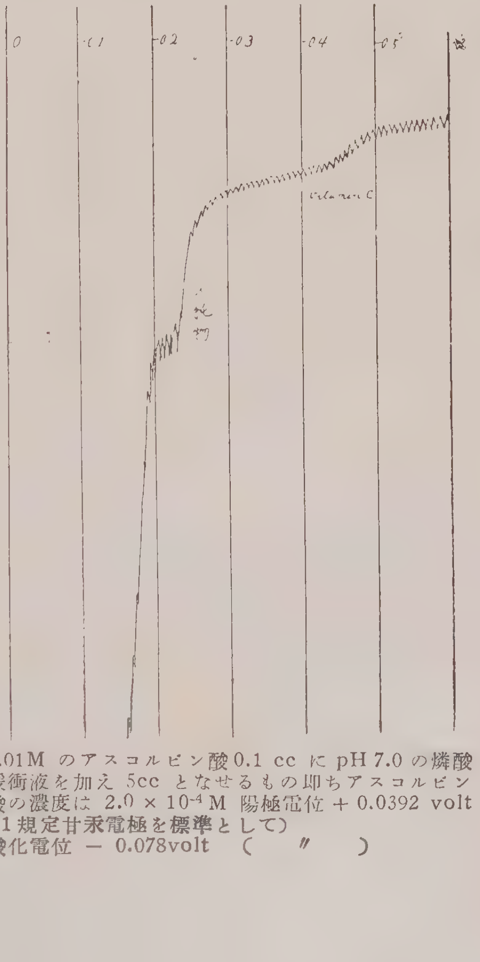
実験の詳細は次の如くである。

實験の部

実験に用いた電流計の感度は 9.8×10^{-9} amp/mm/m (25±1°) のものを用い、実験はすべて室温に於て行い、陽極には陽極面積の大なる硫酸水銀の半電池を用いた。此の際得られたポーラログラムはビタミン C の還元型が酸化された時の波、即ち所謂酸化波で電流は逆に流れている。酸化電位は半還元波法を以て決定し、規定甘汞電極を基準とした値を以て示した。本研究の図に示すポーラログラムは電流計の感度を 1/2 とせるものである。

本研究に用いたアスコルビン酸の純度は 95 % のものである。尚ほ本研究に示すポーラログラムは 1/2 縮尺のものである。

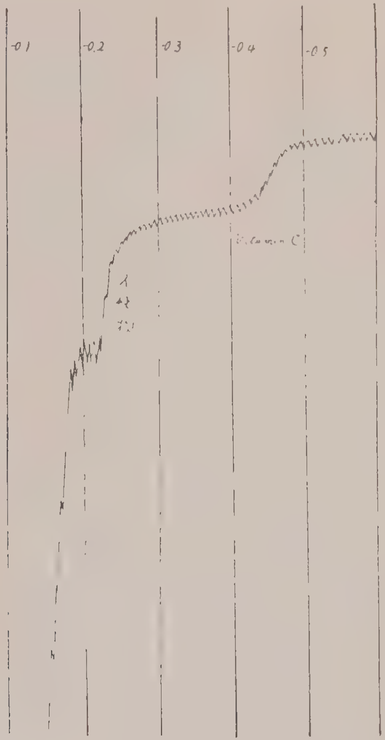
第 1 図



0.01M のアスコルビン酸 0.1 cc に pH 7.0 の燐酸緩衝液を加え 5cc となせるもの即ちアスコルビン酸の濃度は 2.0×10^{-4} M 陽極電位 ＋0.0392 volt（1 規定甘汞電極を標準として）
酸化電位 − 0.078volt （ 〃 ）

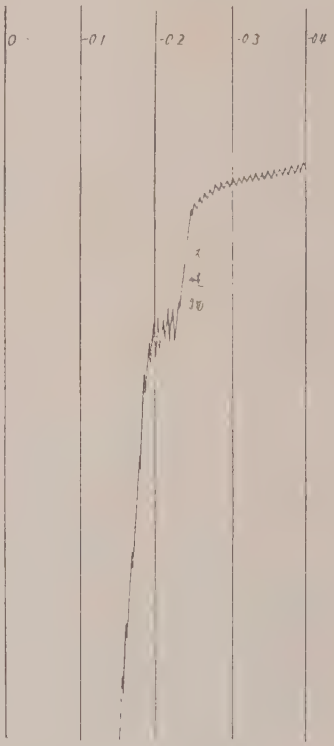
1.　燐酸緩衝液にアスコルビン酸を加えた場合のポーラログラムは第1図及び第2図の如くである。第1図及び第2図に示す如くアスコルビン酸は水銀滴下電極によつて −0.078 volt に於て酸化された。しかし此の如き條件の電解液によつてポーラログラムに現れたアスコルビン酸による波の高さはその濃度が一定でも不定である。これは水素を通ずる間にアスコルビン酸が変化するものと思われる。これでは定量的に應用することは出來ない。それでアスコルビン酸の酸化波の高さを一定にするために次の実験を試みた。

第 2 図



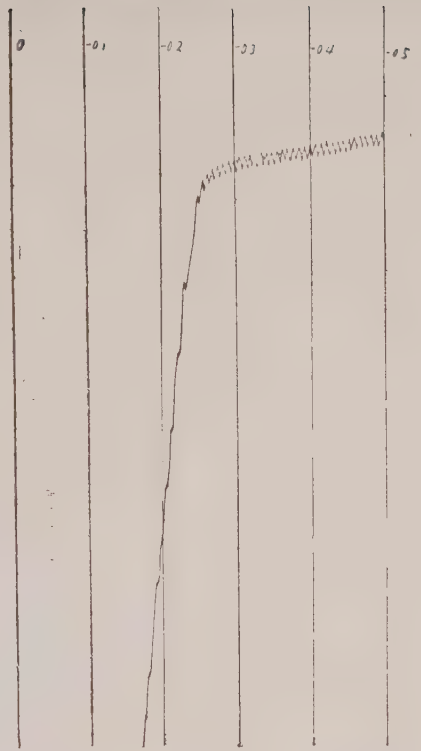
0.01M のアスコルビン酸 0.1 cc に pH 7.0
の燐酸緩衝液を加え 5 cc となせるもの
即ちアスコルビン酸の濃度は 2.0×10^{-4} M
陽極電位 +0.392 volt（1規定甘汞電極を
標準として）
酸化電位 −0.078 volt（　〃　）

第 3 図



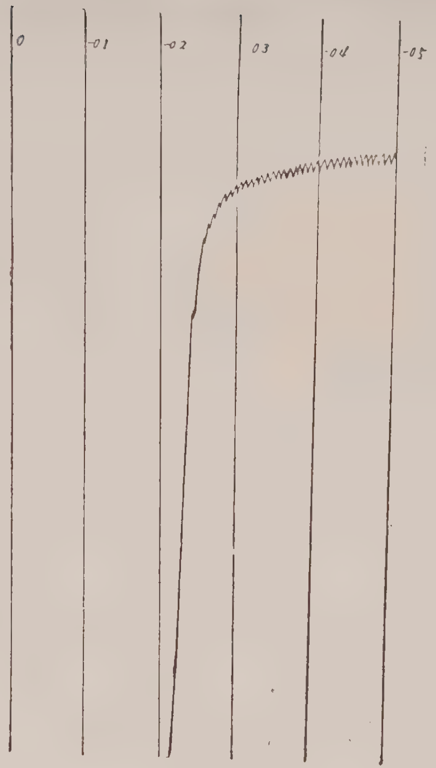
pH 7.0 の燐酸緩衝液 5 cc
陽極電位 +0.393 volt（1規定甘汞電極を標準として）

第 4 図



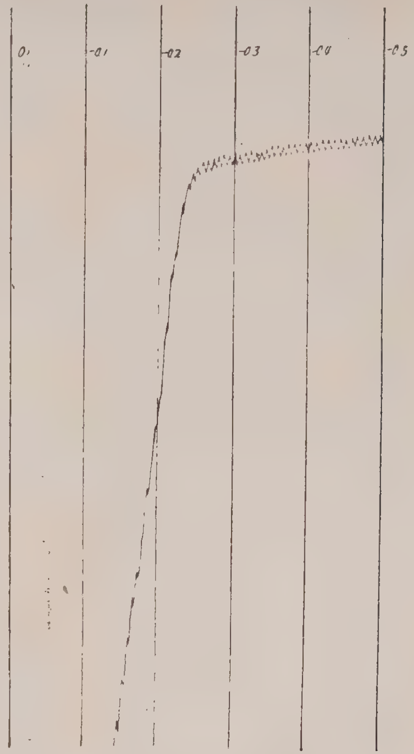
0.1N. KCl 0.1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの

第 5 図



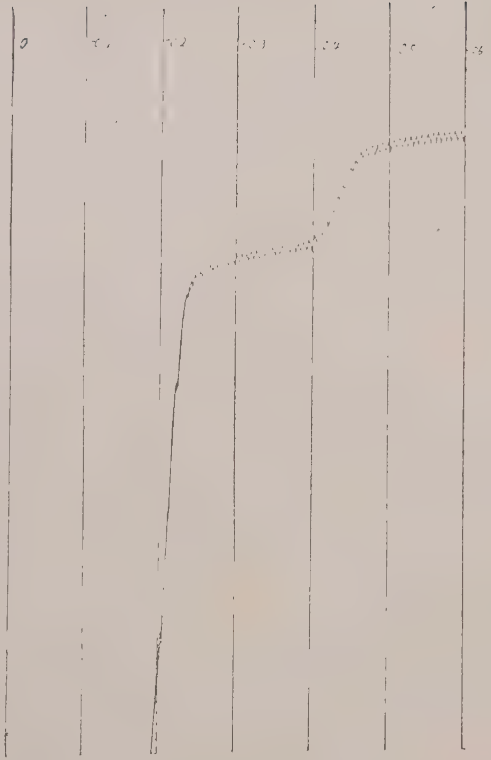
0.01M アスコルビン酸 0.1 cc 及びに 0.1 N KCl 0.1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの

第 6 図



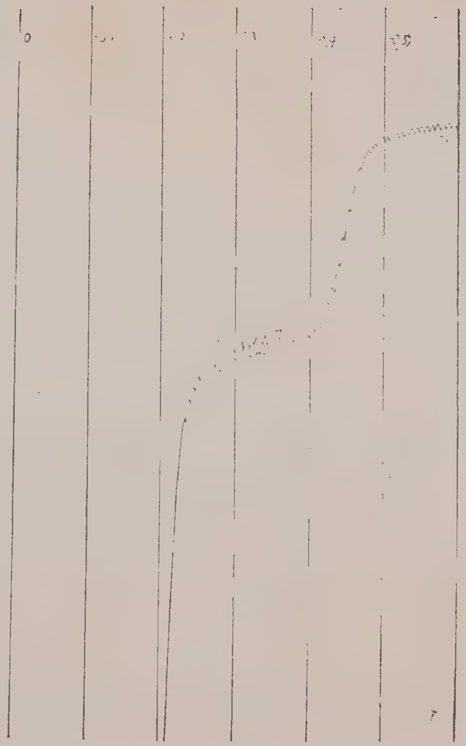
0.1N. KCl 0.1 cc, 0.1M 枸櫞酸 0.1cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの

第 7 図



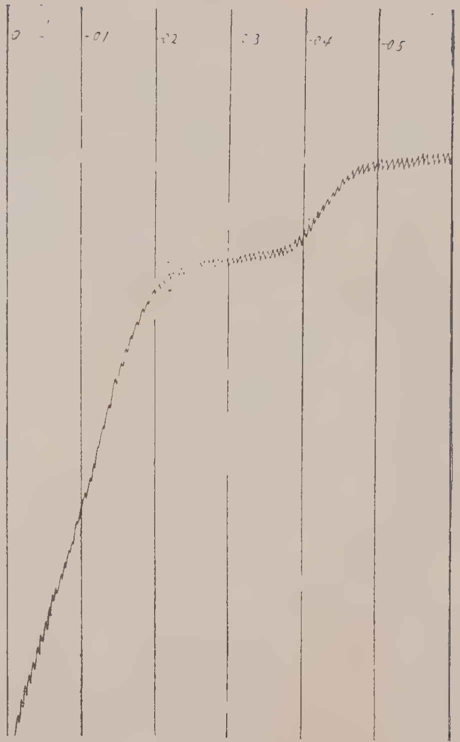
0.1 N KCl 0.1 cc, 0 1 M 枸櫞酸 0.1 cc 及び 0.01M アスコルビン酸 0.1 cc に pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
即ちアスコルビン酸の濃度は 2.0×10-4M
陽極電位＋0.392 volt（1規定甘汞電極を標準として）
酸化電位 −0.028 volt（ 〃 ）

第 8 図



0.1N KCl 0.1 cc, 0.1M 枸櫞酸 0.1 cc 及び 0.01M アスコルビン酸 0.2 cc に pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
即ちアスコルビン酸の濃度は 4.0×10-4M
陽極電位 ＋0.392 volt （1規定甘汞電極を標準として）
酸化電位 −0.048 volt（ 〃 ）

第 9 図



0.1N. KCl 0.1 cc, 0.1M 枸櫞酸加里 0.1 cc 及び 0.01M アスコルビン酸 0.1 cc に pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
即ちアスコルビン酸の濃度は 2.0×10-4M
陽極電位＋ 0.392 volt（1規定甘汞電極を標準として）
酸化電位 ＋0.038 volt（ 〃 ）

2. 燐酸緩衝液のみのポーラログラムは第3図の如くである。

第3図は燐酸緩衝液のみのポーラログラムであつて、一つの酸化波（酸化電位約0.063 volt）あらわれておるが、之は恐らく緩衝液中の不純物の酸化に依る波（多分 Cl′）であろう。第1に不純物と記した波は之れに依るものである。

3. 燐酸緩衝液に塩化加里を加えた場合のポーラログラムは第4図の如くである。

第4図に示す如く燐酸緩衝液に塩化加里を少量加えることによつて、燐酸緩衝液の不純物の波消すことが出來る（Cl′ の増大のために Cl′ の酸化波が大きくなつたのである）。

4. 燐酸緩衝液に塩化加里及びアスコルビン酸を加えた場合のポーラログラムは第5図の如くある。

第5図に示す如く少量の塩化加里を加えることによつて、アスコルビン酸の波は生じなかつ。（此の現象は追究すべき問題である）。

5. 燐酸緩衝液に塩化加里及び枸櫞酸を加えた場合のポーラログラムは第6図の如くである。

第6図に示す如く何等波を生じない。

6. 燐酸緩衝液に塩化加里、枸櫞酸及びアスコルビン酸液を加えた場合のポーラログラムは第−8図の如くである。

第7及び第8図に示す如く少量の枸櫞酸の添加によつて不純物の波は消失し－0.038 volt にてアルコルビン酸の酸化波を現わし、而して其の波の高さは濃度に比例して一定となり、後に示す定量的実例の場合によく一致した値を示す。

故に第7図及び第8図はアスコルビン酸定量の標準ポーラログラムとなすことが出來る。

7. 燐酸緩衝液に塩化加里、枸櫞酸加里及びアスコルビン酸を加えた場合のポーラログラムは第9図の如くである。

第9図に示す枸櫞酸の代りに枸櫞酸加里を用いても第7図の場合と同様に－0.038 volt に於てアスコルビン酸の酸化波を示し、波の高さは第7図の場合と同様である。即ち第9図は第7図の場合と同様にアスコルビン酸定量の標準ポーラログラムとなす事が出來る。

8. 燐酸緩衝液に枸櫞酸を加えた場合のポーラログラムは第10図に示す如くである。

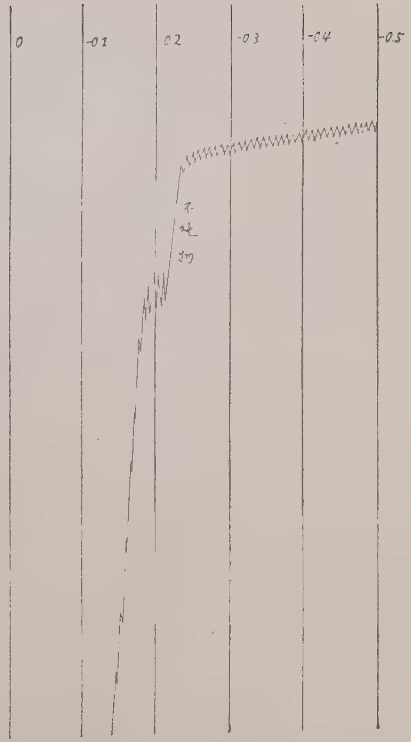
9. 燐酸緩衝液に枸櫞酸及びアスコルビン酸を加えた場合のポーラログラムは第11図の如くである。

第11図に示す如く燐酸緩衝液と枸櫞酸のみにても－0.033 volt にてアスコルビン酸の酸化波生じ、波の高さも第7図の場合と同様である。故に第11図もアスコルビン酸定量の標準ポーラログラムとなすことが出來る。

10. 枸櫞酸緩衝液にアスコルビン酸を加えた場合のポーラログラムは第12図に示す如くである。

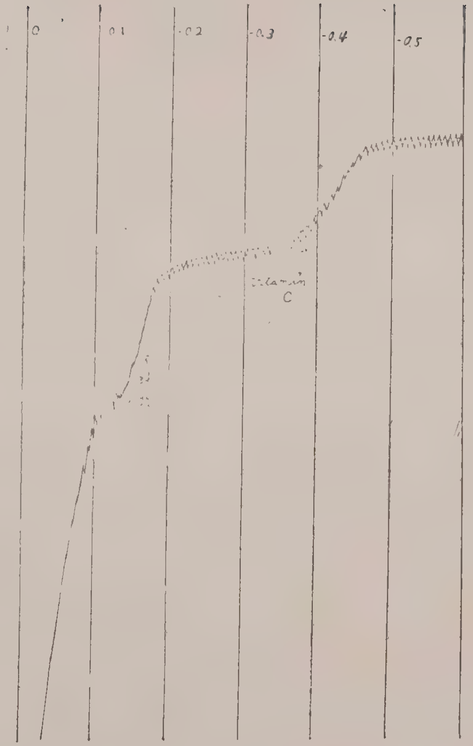
第12図に示す如く枸櫞酸緩衝液を用いる時－0.043 volt にてアスコルビン酸の酸化波を生じ

第 10 図



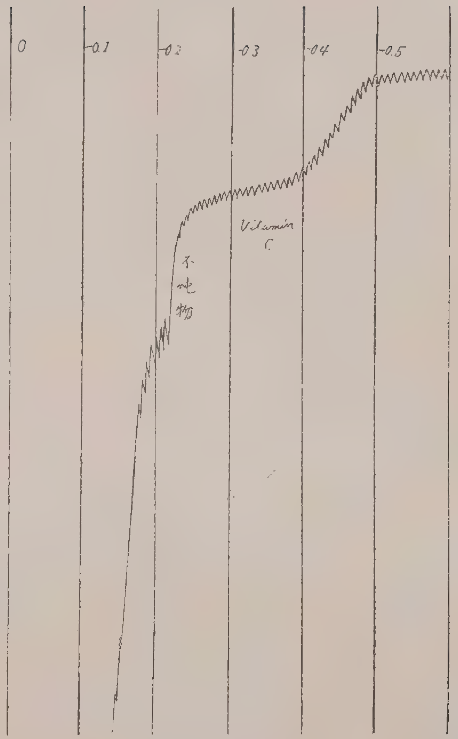
0.1M 枸櫞酸 0.1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 + 0.392 volt（1 規定甘汞電極を標準として）
酸化電位 0 volt　（　〃　）

第 11 図



0.1M 枸櫞酸 0.1cc, 0.01 M アスコルビン酸 0.1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの、即ちアスコルビン酸の濃度は 2.0×10⁻⁴M
陽極電位 + 0.392 volt（1 規定甘汞電極を標準として）
酸化電位 − 0.033 volt（　〃　）

第 12 図



0.01 M アスコルビン酸 0.1 cc に pH 7.0 の枸櫞酸緩衝液を加えて 5 cc となせるもの
即ちアスコルビン酸の濃度は 2.0×10⁻⁴M
陽極電位 + 0.392 volt（1 規定甘汞電極を標準として）
酸化電位 − 0.043 volt（　〃　）

其の波の高さは第7図の場合と同様である。故に第 12 図もアスコルビン酸定量の標準ポーラログラムとなすことが出來る。

11· アスコルビン酸定量の基準となる標準ポーラログラムに於ける條件を表示して見ると、次の第1表の如くである。

第1表を見るにアスコルビン酸定量の標準ポーラログラムに於いてアルコルビン酸の酸化電位

第　1　表

ポーラログラム	アスコルビン酸の濃度	溶　液	酸化電位（アスコルビン酸）	波の高さ	1L中のアスコルビン酸の量
	(M)		(volt)	(mm)	(mg)
第 7 図	2.0×10^{-4}	塩化加里 枸櫞酸 燐酸緩衝液	-0.038	24.0	35.2
第 8 図	4.0×10^{-4}	塩化加里 枸櫞酸 燐酸緩衝液	−0.048	48.0	70.4
第 9 図	2.0×10^{-4}	塩化加里 枸櫞酸加里 燐酸緩衝液	−0.033	24.0	35.2
第 11 図	2.0×10^{-4}	枸櫞酸 燐酸緩衝液	−0.033	24.0	35.2
第 12 図	2.0×10^{-4}	枸櫞酸緩衝液	−0.048	24.0	35.2

は一規定甘汞電極を基準としてすべて約 −0.040 volt であり、同一のアスコルビン酸濃度にては同じ高さの酸化波を生じ、その波の高さは濃度に比例している。而して此の波の高さは後に示す定量的実例の場合に於ける、蜜柑果汁及び乾海苔浸出液にアスコルビン酸を加えたる場合とよく一致し、定量的に波の高さが増加している。故に第1表に示す條件に於けるポーラログラムは全くビタミン C 定量の標準となすことが出來る。

アスコルビン酸の溶液中に枸櫞酸又は枸櫞酸加里を加えなければ、第1図及び第2図に示す如くアスコルビン酸の一定濃度に対し、常に一定の高さの波を生じない。これは他の有機酸及びその塩類を以てしても代用し得るものと思う。故にポーラログラフ法に於て、枸櫞酸又は枸櫞酸加里の混入は本実験の範囲に於いては絶対に必要と思われる。

多分枸櫞酸並びにその塩類はビタミン C に対して一種の安定剤として作用するものであろう。

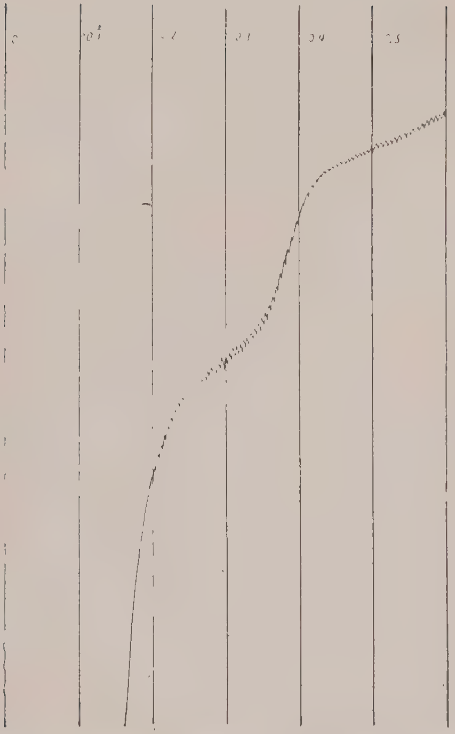
12· ビタミン C の定量的実例

(1) 蜜柑果汁中のビタミン C の定量

蜜柑果汁に燐酸緩衝液を加えた場合のポーラログラムは第 13 図の如くである。更にこれにアスコルビン酸を加えた場合のポーラログラムは第 14 図の如くである。

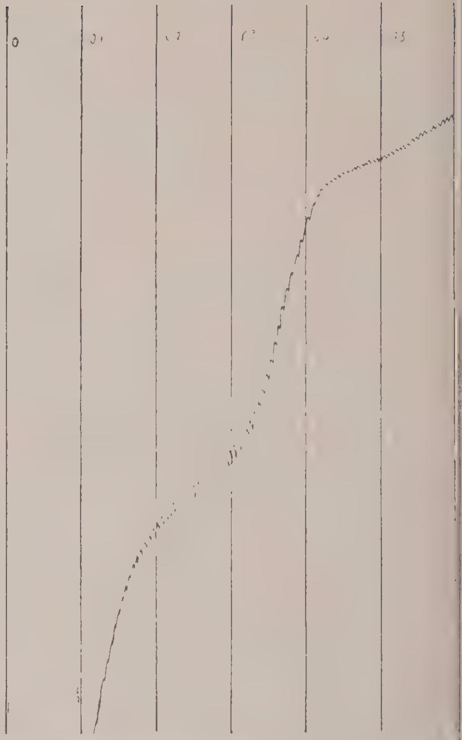
第 13 図に示す如く蜜柑果汁中のビタミン C は +0.042 volt に於て酸化波を示す。この酸化電位は前記第1表に示すアスコルビン酸の酸化電位と比較するに約 0.1 volt の相違がある。しかし第 14 図に示す蜜柑果汁にアスコルビン酸を加えたるポーラログラムを見るに、+0.042 volt

第 13 図



蜜柑果汁を濾過し、濾液 1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 +0.422 volt（1 規定甘汞電極を標準として）
酸化電位 +0.042 volt（　〃　）

第 14 図



蜜柑果汁濾液 1 cc に 0.01M. アスコルビン酸 0.1
を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるも
陽極電位 +0.412 volt（1 規定甘汞電極を標準
して
酸化電位 +0.042 volt（　〃

に於て、加えたるアスコルビン酸の量に比例して波が高くなつている。これを以て見るに +0.0 volt にて現われる蜜柑果汁の波は、蜜柑果汁中のビタミン C なることが確実に証明出來た次である。

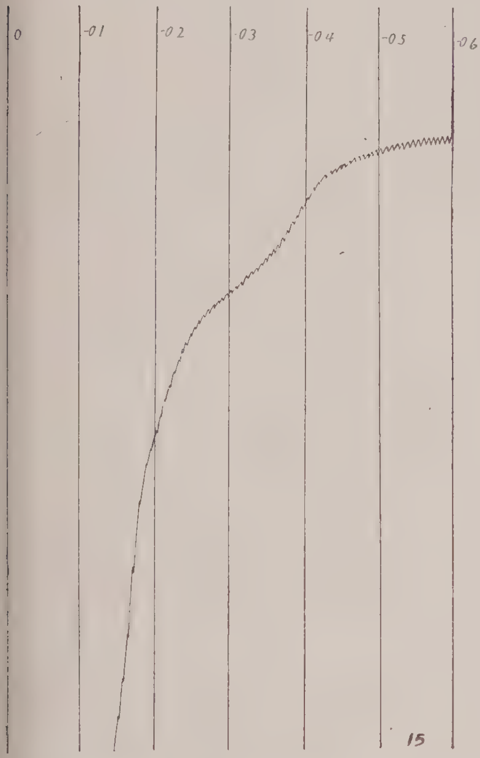
次に第 13 図、第 14 図並びにアスコルビン酸の標準ポーラログラムより定量的に考究してるに、蜜柑果汁 1 cc に相当したアスコルビン酸の波の高さは 38mm、蜜柑果汁 1 cc に 0.0 のアスコルビン酸 0.1 cc を加えたるものの波の高さは 62mm であつて、其の波の高さの差 mm は加えたるアスコルビン酸（濃度は2.0×10^{-4}M）の波の高さと完全に一致している。故に れによつて完全に定量出來る。即ち蜜柑果汁中には 27.9mg% のビタミン C を含有する。標 アスコルビン酸の純度は 95% なる故 26.5mg% となる。

尙藤田岩竹氏(20) のインドフエノール法により定量せるに蜜柑果汁中のビタミン C の含量は 25.4mg% であつて大体一致した結果を示す。

（2） 乾海苔中のビタミン C の定量

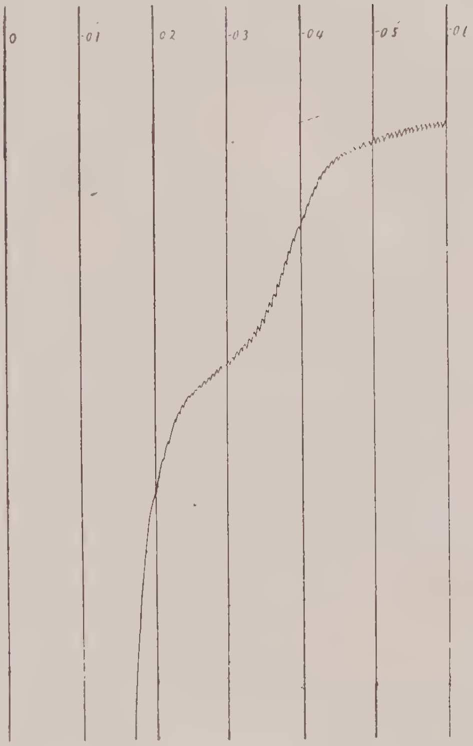
乾海苔を燐酸緩衝液にて浸出したるもののポーラログラムは第 15 図、尚之にアスコルビン酸を加えたるもののポーラログラムは第 16 図の如くである。

第 15 図



乾海苔 1 枚を pH 7.0 の燐酸緩衝液 50 cc にて浸出し、其の 5 cc を用う。
陽極電位 +0.428 volt（1 規定甘汞電極を標準として）
酸化電位 +0.043 volt（　〃　）

第 16 図



第 15 図と同様、浸出液 4.9 cc に 0.01 M アスコルビン酸 0.1 cc を加えたるもの
陽極電位 +0.428 volt（1 規定甘汞電極を標準として）
酸化電位 +0.043 volt（　〃　）

第 15 図に示す如く、乾海苔の酸化電位は標準アスコルビン酸の酸化電位とは多少相違しているが、第 16 図に示す如く之にアスコルビン酸を加えたるポーラログラムを見れば、蜜柑果汁の場合と同様に、同一電位に於て加えたるアスコルビン酸の量に比例して波が高くなつている。故に +0.043 volt に生ずる波は乾海苔中のビタミン C なることが証明せられる。

次に定量的に考究して見ると、第 15 図の波の高さは 21 mm 、之にアスコルビン酸を加えたる第 16 図の波の高さは 45 mm であつて、其の差は丁度加えたアスコルビン酸の波の高さ 24 mm に相当する。即ち乾海苔中のビタミン C の含量は 61.60 mg% となる。但し用いた標準アスコルビン酸の純度は 95% であるから乾海苔中のビタミン C の含量は 58.52 mg % である。

尚藤田、岩竹氏のインドフエノール法により定量せるに乾海苔中のビタミン C の含量は 57.1

mg% であつて大体一致した値を示す。

13. ポーラログラフ法によるビタミンCの定量とインドフェノール法によるものとの比較

蜜柑果汁及び乾海苔中のビタミンC定量の結果をポーラログラフ法によるものとインドフノール法によるものとを比較すると、第2表及び第3表に示す如くである。

第 2 表

試料	定量法	酸化電位（ビタミンC）	波の高さ	蜜柑果汁1cc中のビタミンC含有量	蜜柑果汁100cc中のビタミンC含有量（標準アスコルビン酸の純度を95％として）
		(volt)	(mm)	(mg)	(mg)
蜜柑果汁	ポーラログラフ法	+0.042	38	0.279	26.5
蜜柑果汁	インドフェノール法				25.4

第 3 表

試料	定量法	酸化電位（ビタミンC）	波の高さ	乾海苔1枚(2.5g)中のビタミンC含有量	乾海苔100g中のビタミンC含有量（標準アスコルビン酸の純度を95％として）
		(volt)	(mm)	(mg)	(mg)
乾海苔	ポーラログラフ法	+0.043	21	1.54	58.52
乾海苔	インドフェノール法				57.1

第2表及び第3表に示す如く蜜柑果汁及び乾海苔中のビタミンCの定量に関しては、ポーラグラフ法によるもインドフェノール法によるも、大体一致した結果を示すが、ポーラログラフよる方が幾分高い結果を示している。しかし第13、14、15、16図に見る如くアスコルビン酸をえたる場合ビタミンCの酸化波の高さが定量的に増加し、其の波の高さの差が加えたる純アスルビン酸の波の高さと一致する点より見れば、ポーラログラフによる定量の方が正確であろう

尚ポーラログラフ法による時は、一度アスコルビン酸の標準ポーラログラムを撮れば、之を準として定量を行う事が出來て短時間に簡單に定量することが出來る。

更にポーラログラフ法の利点はビタミンC以外の還元性物質の影響が全然ない事である。故動植物組織に應用して完全で正確な定量が出來ると考えられる。

要 旨

1. アスコルビン酸は單に燐酸緩衝液に溶かしたのみではその濃度に應じて常に一定のポーログラムは得られなかつた。それは水素を通ずる際に變化を起すためと思われる。

2. 塩化加里を加えた燐酸緩衝液ではアスコルビン酸の酸化波はポーラログラムに現れなかた。しかし之は枸櫞酸を加える事によつて塩化加里の影響はなくなつた。

3. 燐酸緩衝液に枸櫞酸又は枸櫞酸加里を加えた場合アスコルビン酸はその濃度に比例して化波を示す。又枸櫞酸緩衝液を加えた場合も同樣である。これによつて見るにアスコルビン酸

対して枸櫞酸並びにその塩類は一種の安定剤と思われる。アスコルビン酸定量の標準ポーラログラムを得るためには枸櫞酸又はその塩類添加は本実験に於ては絶対に必要であつた。これは多分他の有機酸を以てしても代用し得ることと思う。最も簡單にアスコルビン酸定量の標準ポーラログラムを得るためには、アスコルビン酸を枸櫞酸緩衝液に溶かせばよい。

4. ポーラログラフ法による定量的実例に於ては密柑果汁及び乾海苔中のビタミン C の酸化電位はアスコルビン酸の標準液に於ける酸化電位と約 0·1 volt 異るが、蜜柑果汁及び乾海苔にアコスルビン酸を加えて見るに、同一電位に於て定量的に波の高さを増加する事よりビタミン C なる事は確実に証明せられる。

5. ポーラログラフ法による時は密柑果汁中には 26·5 mg%、乾海苔中には 58.52 mg%、のビタミン C を含有するが、インドフエノール法による時は蜜柑果汁中には 25·4 mg%、乾海苔中には 57·1 mg% のビタミン C 含有量であつた。ポーラログラフ法による方が多少多い結果を示すがポーラログラフ法による結果の方が寧ろ正確に近いかも知れない。何となればポーラログラフ法では一般に微量にて還元又は酸化波を示すから。

6. ポーラログラフ法の利点は一度アスコルビン酸のポーラログラムを撮つて置けば非常に簡單に短時間にビタミン C の定量が出來る。

7. 本実験に示したポーラログラムはビタミン C の還元型が酸化される時のものであつて、電流は逆に流れている。從つて本研究はビタミン C の還元型のみに就いて行つたものである。

第 2 章

水素イオン濃度の影響

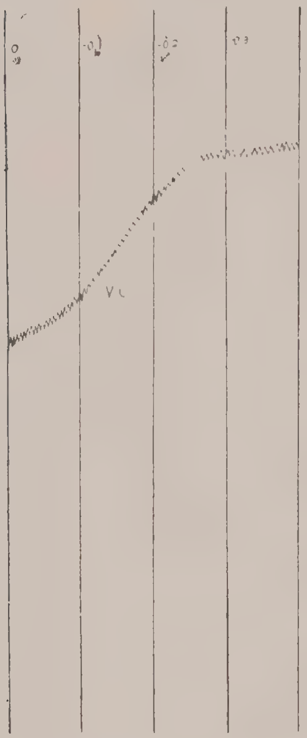
第 1 章に述べたアスコルビン酸定量の標準ポーラログラムはすべて pH 7·0 の溶液中にて実験を行つたものである。それで、次に水素イオン濃度が如何にアスコルビン酸のポーラログラムに影響するかを確めるため次の実験を行つた。

實験の部

実験に用いた電流計の感度は 9.8×10^{-9} amp/mm/m (25±1°) のものを用い、実験はすべて室温に於て行い、陽極面積の大なる硫酸水銀の半電池を用いた。此の際得られたポーラログラムはビタミン C の還元型が酸化される時の波、即ち所謂酸化波で電流は逆に流れている。酸化電位は半還元波法を以て決定し 1 規定甘汞電極を基準とした値を以て示した。本研究の図に示すポーラログラムは、電流計の感度を 1/2 とせるものである。本研究に用いたアスコルビン酸の純度は 95 % のものである。第 1 章に於て燐酸或は枸櫞酸何れの緩衝液を用いても pH 7·0 に於て同

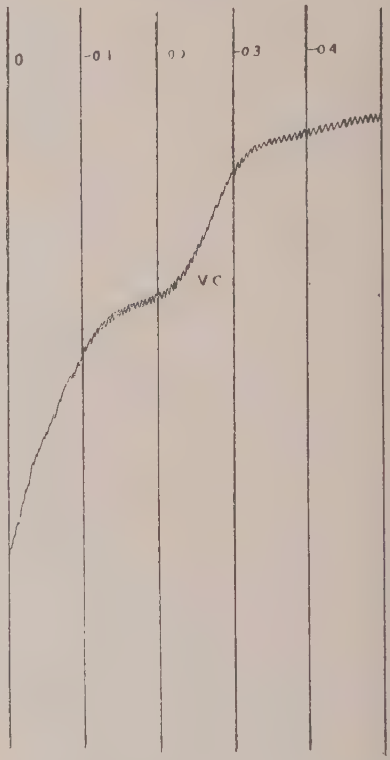
一の波の高さのポーロラグラムが得られた。それで水素イオン濃度がアスコルビン酸のポーラグラムに如何に影響するかを見るため、枸櫞酸緩衝液を用い pH 2.2 より pH 8.0 までに於てーラログラムを撮つた。

第 17 図



0.01 M アスコルビン酸 0.1 cc に pH 2.2 の枸櫞酸緩衝液を加え 5 cc となせるもの
即ちアスコルビン酸の濃度は 2.0× 10⁻⁴ M
陽極電位 +0.394 volt（1規定甘汞電極を標準として）
酸化電位 +0.244 volt（ 〃 ）

第 18 図



0.01 M アスコルビン酸 0.1 cc に pH 3.0 の枸櫞酸緩衝液を加え 5 cc となせるもの
即ちアスコルビン酸の濃度は 2.0× 10⁻⁴ M
陽極電位 +0.392 volt（1規定甘汞電極を標準として）
酸化電位 +0.122 volt（ 〃 ）

1. pH 2.2 の枸櫞酸緩衝液にアスコルビン酸を溶解せる場合のポーラログラムは第 17 図の くである。第 17 図に示す如く pH 2.2 にては +0.244 volt にて酸化波を生じ、波の高さは mm である。

2. pH 3.0 の枸櫞酸緩衝液にアルコルビン酸を溶解せる場合のポーラログラムは第 18 図に す如くである。

第 18 図に示す如く pH 3.0 にては +0.122 volt に於て酸化波を生じ、波の高さは 36mm ある。

3. pH 4.0 の枸櫞酸緩衝液にアスコルビン酸を溶解せる場合のポーラログラムは第 19 図の

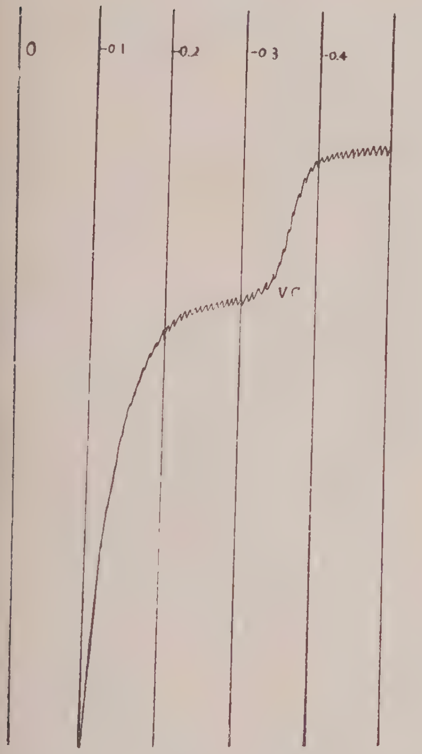
くである。

第19図に示す如く pH 4.0 にては ＋0.057 volt にて酸化波を生じ、波の高さは 34 mm である。

4. pH 5.0 の枸櫞酸緩衝液にアスコルビン酸を溶解せる場合のポーラログラムは第 20 図の如くである。

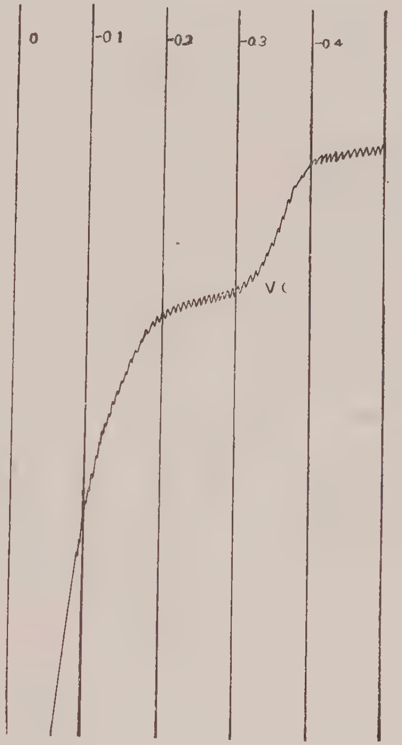
第 20 図に示す如く pH 5.0 にては ＋0.003 volt にて酸化波を生じ、波の高さは 32 mm である。

第 19 図



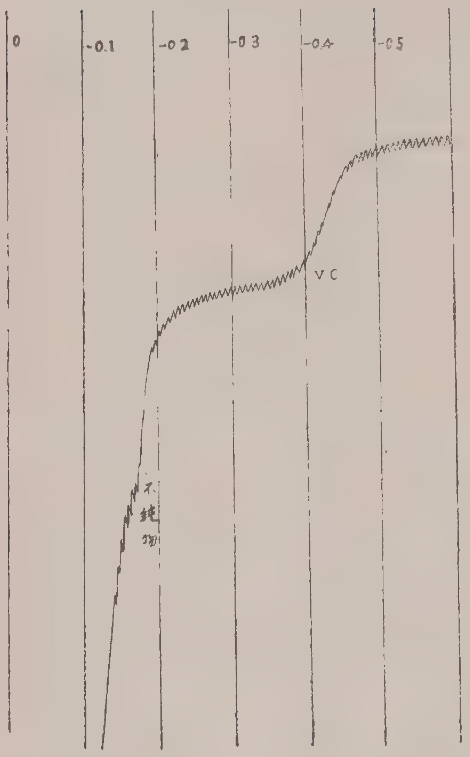
0.01 M アスコルビン酸 0.1 cc に pH 4.0 の枸櫞酸緩衝液を加えと 5 cc なせるもの
即ちアスコルビン酸の濃度は 2.0×10^{-4}M
陽極電位 ＋0.419 volt（1規定甘汞電極を標準として）
酸化電位 ＋0.057 volt（ 〃 ）

第 20 図



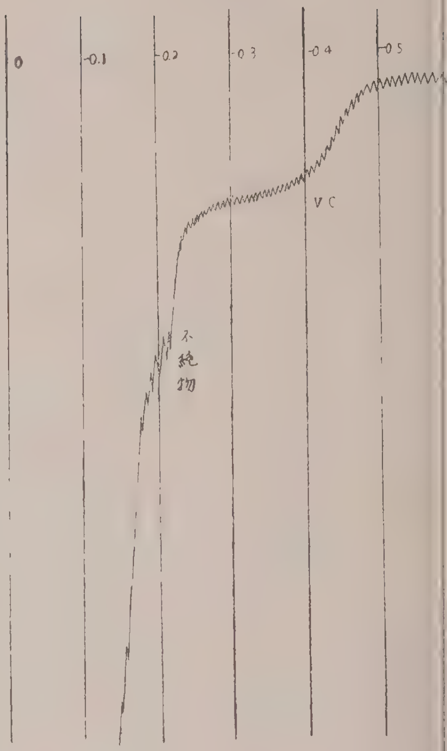
0.01 M アスコルビン酸 0.1 cc に pH 5.0 の枸櫞酸緩衝液を加え 5 cc となせるもの
即ちアスコルビン酸の濃度は 2.0×10^{-4}M
陽極電位 ＋0.363 volt（1規定甘汞電極を標準として）
酸化電位 ＋0.003 volt（ 〃 ）

第 21 図



0.01 M アスコルビン酸 0.1 cc に pH 6.0 の枸櫞酸緩衝液を加え 5 cc となせるもの即ちアスコルビン酸の濃度は 2.0×10^{-4}M
陽極電位 +0.392 volt（1規定甘汞電極を標準として）
酸化電位 +0.035 volt（　〃　）

第 22 図



0.01 M アスコルビン酸 0.1 cc に pH 7.0 の
櫞酸緩衝液を加え 5 cc となせるもの即ちア
コルビン酸の濃度は 2.0×10^{-4}M
陽極電位 +0.389 volt（1規定甘汞電極を標
として
酸化電位 −0.055 volt（　〃

5.　pH 6.0 の枸櫞酸緩衝液にアスコルビン酸を溶解せる場合のポーラログラムは第21図の
くである。

第21図に示す如く pH 6.0 にては −0.035 volt にて酸化波を生じ、波の高さは 29mm であ

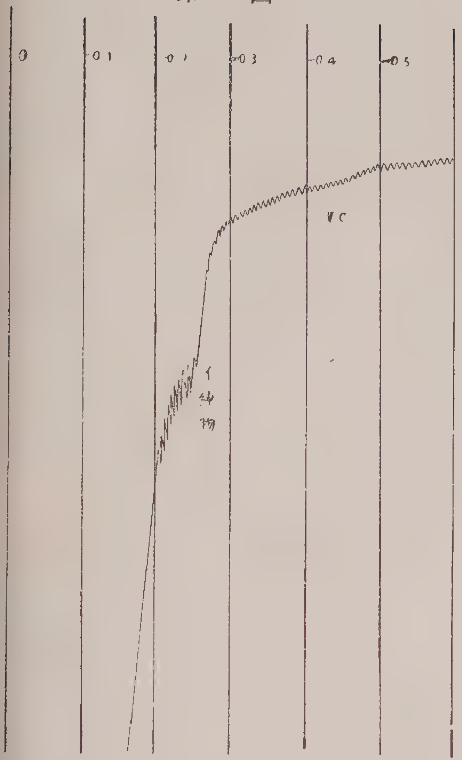
6.　pH 7.0 の枸櫞酸緩衝液にアスコルビン酸を溶解せる場合のポーラログラムは第22図
くである。

第22図に示す如く pH 7.0 にては −0.055 volt にて酸化波を生じ、波の高さは 24mm であ

7.　pH 8.0 の枸櫞酸緩衝液にアスコルビン酸を溶解せる場合のポーラログラムは第23図の
くである。

第23図に示す如く pH 8.0 にては −0.081 volt にて酸化波を生じ、波の高さは 2 mm であ
pH 8.0 にて急激に酸化波の高さが減少して来る。繰返して実験を行つて見たが同様なポー

第 23 図



0.01 M. アスコルビン酸 0.1 cc に pH 8.0 の枸櫞酸緩衝液を加えて 5 cc となせるもの即ちアスコルビン酸の濃度は 2.0×10^{-1}M
陽極電位 +0.394 volt（1規定甘汞電極を標準として）
酸化電位 −0.081 volt（　〃　）

ログラムが得られた。これによつて見るにアルカリ性になるとアスコルビン酸は不安定になるものと思われる。従つて酸化波は殆んど生じない。

8. 以上の結果を綜合して見ると第4表の如くである。

9. アスコルビン酸の酸化波の高さと pH との関係を図示すると第 24 図の如くである。

第 24 図に示す如く pH 2.2 にては酸化波の高さは 40 mm であるが、pH の増加に従い酸化波の高さは漸減し、pH 7.0 にては 24 mm となり、pH 8.0 に至つて 2 mm となり、急激に酸化波の高さが減少して来る。これは液性がアルカリになるとアスコルビン酸が不安定になるからであろうと思われる。

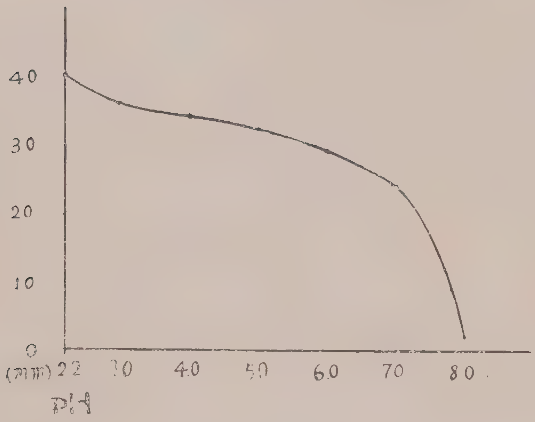
10. アスコルビン酸の酸化電位と pH との関係を図示すると第 25 図の如くである。

第 25 図に示す如く酸化電位は pH 22 にては +0.244 volt で pH の増加に従い漸次減少し pH 5.0 にて殆んど 0 volt となり、更に減少して pH 8.0 にては −0.081 volt となる。

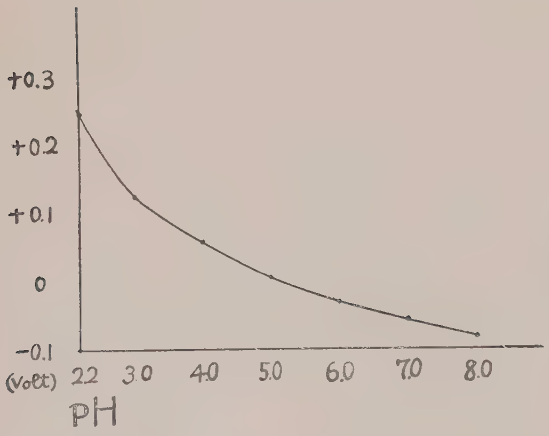
第 4 表

ポーラログラム	pH	溶　液	アスコルビン酸の濃度（M）	酸化電位（アスコルビン酸）(volt)	波の高さ (mm)	1L中のアスコルビン酸の量 (mg)
第 17 図	2.2	枸櫞酸緩衝液	2.0×10^{-4}	+0.244	40	35.2
第 18 図	3.0	〃	〃	+0.122	36	〃
第 19 図	4.0	〃	〃	+0.057	34	〃
第 20 図	5.0	〃	〃	+0.003	32	〃
第 21 図	6.0	〃	〃	−0.035	29	〃
第 22 図	7.0	〃	〃	−0.055	24	〃
第 23 図	8.0	〃	〃	−0.081	2	〃

第 24 図



第 25 図



要　　旨

1. ビタミン C のポーラログフ的研究に於て水素イオン濃度が何に影響するかを見るため、枸櫞緩衝液を用い、pH 2.2 より pH 8でのポーラログラムを撮つた。

2. アスコルビン酸の酸化波のさは、その濃度 2.0×10^{-4}M にてpH 2.2 の場合は 40 mm、それよpH の増加に従い酸化波の高さは次減少し、pH 7.0 にては 24 mmなり、pH 8.0 になると急激に酸化の高さは減少して 2 mm となる。即ち液性がアルカリ性になるとアコルビン酸は不安定となつて、殆ど酸化波を生じないのであろう。

3. アスコルビン酸の酸化電位その濃度 2.0×10^{-4}M にて、pH の場合は +0.244 volt それよりの増加に従い漸次減少して pH にて殆んど 0 volt となり、更にの増加に従い減少して pH 8.0 にて −0.081 volt となる。

第　3　章

果實罐詰中のビタミン C 含有量に就いて

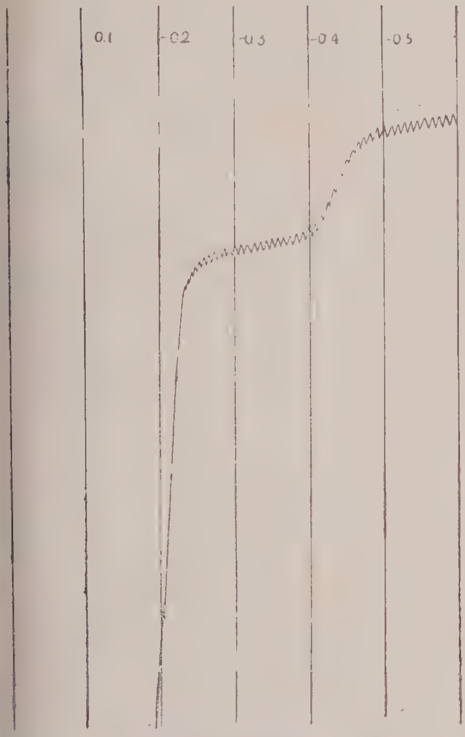
罐詰中のビタミン C の研究に関しては 平野、小沢(21)、岩崎、小松(22)、平野(23−25)、志賀、田(27)、幸野(28)、兒玉、中山(29)、桑原(30)、鯵坂(31)、稲垣(32)、Eddy and Kohman(33) の諸氏の告がある。以上は何れもインドフエノールを用いて研究を行つたものである。著者は第 1 章にせる如くポーラログラフ法によりビタミン C の定量が可能であるので、果実罐詰中のビタミC 含有量の定量を試みた。

實験の部

実験に用いた電流計の感度、陽極には硫酸水銀の半電池を用いる事等、其の他すべての條件は第1章及び第2章と同様である。

実験に用いた罐詰の種類は枇杷、林檎、和梨、洋梨、桃（アーリー、エルバーター)、桃（傳十郎)、栗、蜜柑（試料A)、密柑（試料B)、トマトジュース、トマト（ソリツドパツク)、オレンジジュース、クリームスタイルコーンの13種及び林檎ジュースの壜詰1種である。罐詰中及び壜詰中の液汁は濾過した濾液にpH 7.0の燐酸緩衝液を加えたものを用い、果肉は少量の海砂を加えpH 7.0の燐酸緩衝液を加えて充分に磨砕し、遠心分離して濾過したものを用いた。液汁及び果肉の分離し難いものは内容物全部を処理して用いた。

第 26 図



0.1 N. KCl 0.1cc, 0.1M 枸櫞酸 0.1 cc 及び 0.01M アスコルビン酸 0.1 cc に pH＝7.0 の燐酸緩衝液を加えて 5 cc となせるもの即ちアスコルビン酸の濃度は 2.0×10^{-4}M 陽極電位 +0.392 volt
（1規定甘汞電極を基準として、以下同様)
酸化電位 −0.038 volt

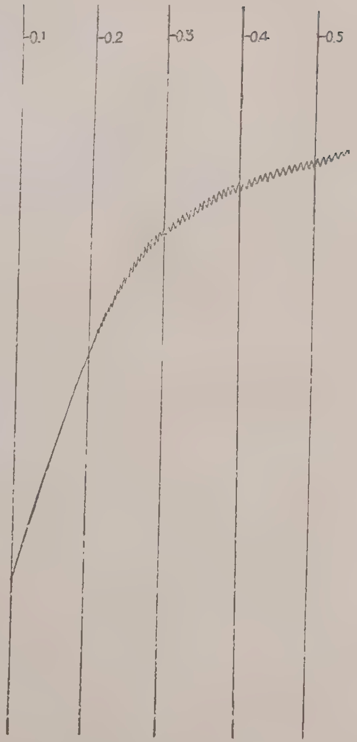
1. ビタミン C 定量の基準となる標準ポーラログラムは、第1章に示せるものと同様であつて、第26図に示すものを用いた。

第26図に示す如くアスコルビン酸は −0.038 volt にて酸化波を生じ、その波の高さは 24 mm である。これをビタミン C 定量の標準ポーラログラムとなす。

2. 枇杷罐詰液汁のポーラログラムは第27図、同果肉は第28図の如く何等の酸化波を生じない。依つて枇杷罐詰中にはビタミン C を含有しない。

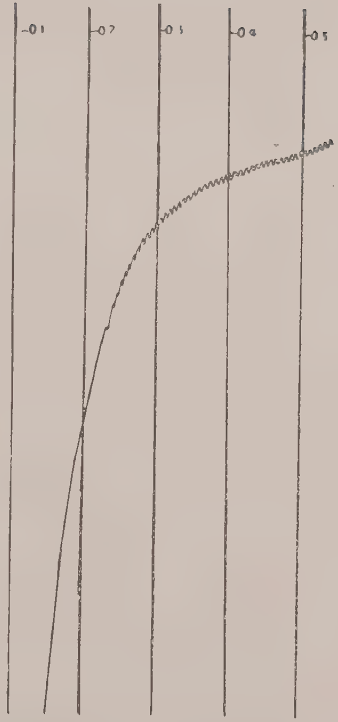
3. 林檎罐詰（ソリツドパツク）液汁及び果肉のポーラログラムは第29図及び第30図の如くで液汁は −0.020 volt にて酸化波を生じ、その波の高さは 6 mm である。即ちアスコルビン酸の標準ポーラログラムを基準としてビタミン C の含有量は 4.40 mg% となる。但しアスコルビン酸の純度が 95 % であるから 4.18 mg% のビタミン C 含有量となる。果肉は −0.162 volt にて多少の酸化波を生じている。しかしこの電位は他のものと比較して大分異るので、これを確めるために次の実験を試みた。即ち果肉を前記同様に処理せる液に極く少量のアスコルビン酸を添加してポーラログラムを撮つた。その結果は第31図に示す如く少量のアスコルビン酸を加えたるも

第 27 図



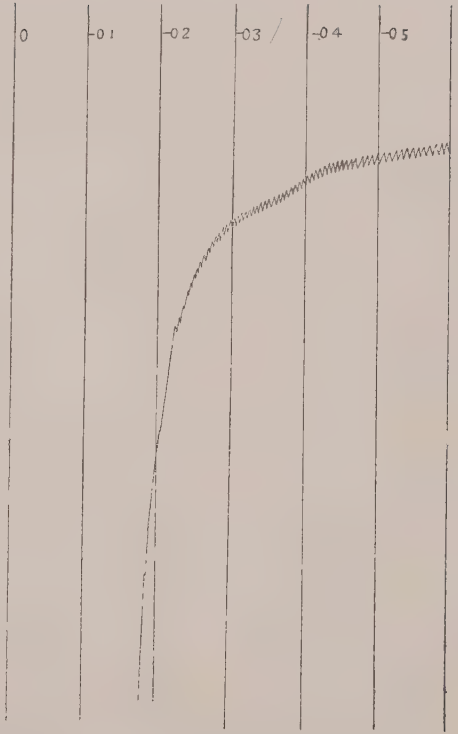
枇杷罐詰液汁 2 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの

第 28 図



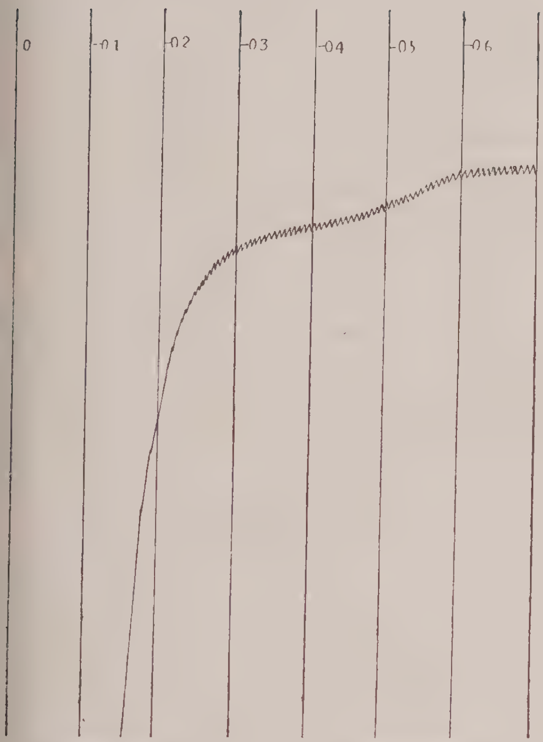
枇杷罐詰果肉 30 g を pH 7.0 の燐酸緩衝液にて処理しその 5 cc を用う

第 29 図



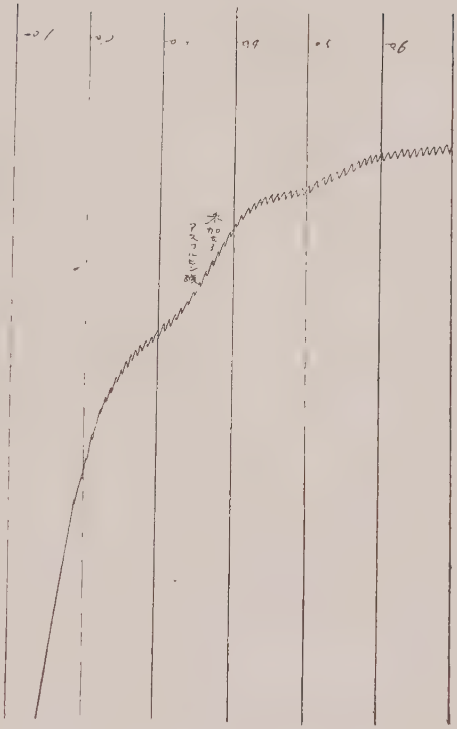
林檎罐詰液汁 2 cc に pH 7.0 の燐酸緩衝液を加え 5 ccとなせるもの
陽極電位 ＋0.377 volt
酸化電位 －0.020 volt

第 30 図



林檎罐詰果肉 10 g を pH 7.0 の燐酸緩衝液にて処理し 30 cc となし、その 5 cc を用う
陽極電位 ＋ 0.378 volt
酸化電位 − 0.020 volt

第 31 図



林檎罐詰果肉を第 5 図と同様に処理し少量のアスコルビン酸を加えたるもの 5 cc を用う
陽極電位 ＋ 0.393 volt
（アスコルビン酸）酸化電位 ＋ 0.016 volt
酸化電位 − 0.160 volt

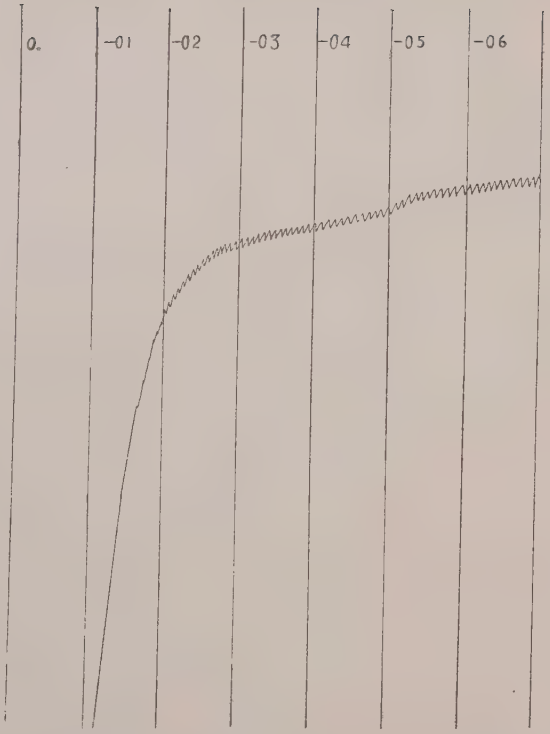
のは、＋0.016 volt 及び −0.160 volt に於て 2 段の酸化波を生じ、添加せるアスコルビン酸は ＋0.016 volt にて酸化波を生ず。依つて −0.160 にて生ずる酸化波はビタミン C でないことが証明せられる。

これはビタミン C に附随して而もビタミン C に似た酸化圧を示すものであろう。

以上の結果より林檎罐詰液汁中にはビタミン C を含有するが、果肉中には含有しいことがわかつた。

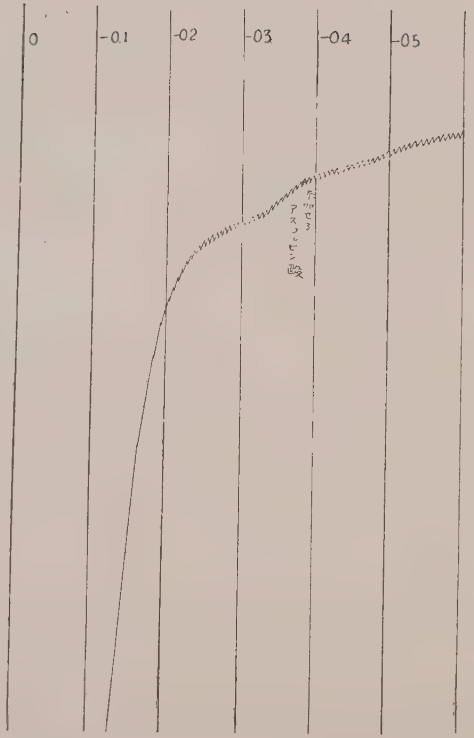
4. 林檎ジュース壜詰液汁のポーラログラムは第 32 図の如く −0.123 volt にて僅かながら酸化波を生じている。これも林檎果肉の場合と同様に酸化電位が大分異るので、之を確めるため林檎ジュース液汁に少量のアスコルビン酸を加えたもののポーラログラムを撮つて見た。その結果は第 33 図の如くで添加せる少量のアスコルビン酸は ＋0.022 volt に於て酸化波を生ずる。依つて −0.123 volt にて僅かながら生ずるものはビタミン C の酸化波でないことがわかる。即ち林檎ジュース壜詰中にはビタミン C は含有しない。林檎罐詰果肉及び林檎ジュース液汁のポ

第 32 図



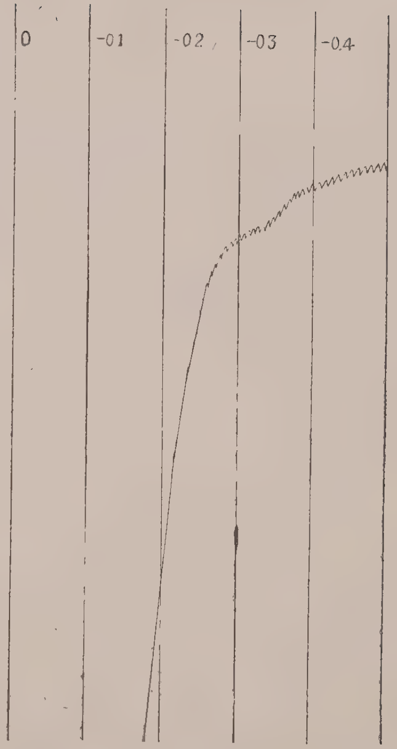
林檎ジュース壜詰液汁 2 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 ＋ 0.392 volt
酸化電位 ＋ 0.123 volt

第 33 図



林檎ジュース液汁 2 cc に少量のアスコルビン酸を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
陽極電位 ＋ 0.388 volt
（アスコルビン酸）酸化電位 ＋ 0.022 volt
酸化電位 － 0.123 volt

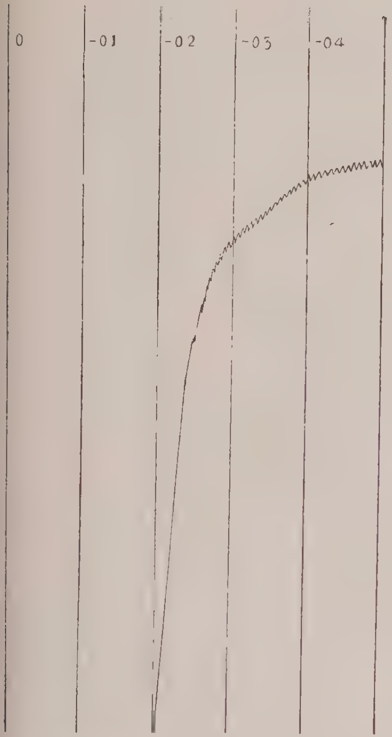
第 34 図



和梨罐詰液汁 2 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 ＋ 0.383 volt
酸化電位 － 0.021 volt

ーラログラムに於て、ビタミン C と異る酸化波が得られる。これによつて見るに林檎中には何らかビタミン C に附随して而もビタミン C に似た酸化圧を示すものの存在が予想される。

第 35 図



和梨罐詰果肉 10 g を pH 7.0 の燐酸緩衝液にて処理し 30 cc となし、その 5 cc を用う
陽極電位 ＋ 0.382 volt
酸化電位 － 0.022 volt

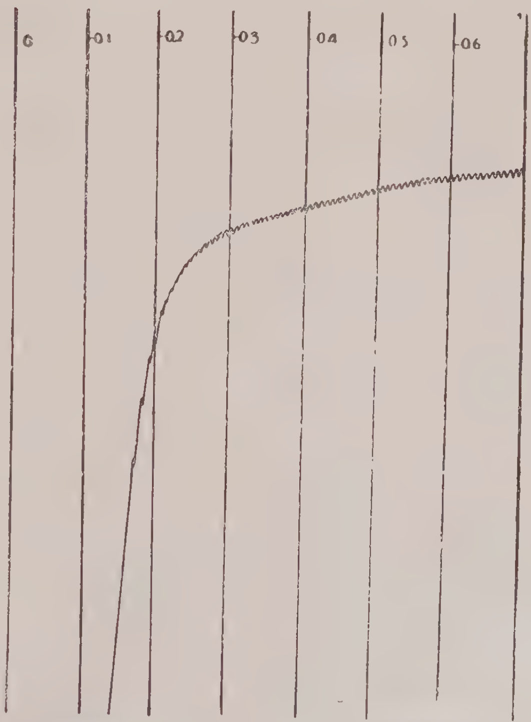
5. 和梨罐詰（長十郎）の液汁及び果肉のポーラログラムは第 34 図及び第 35 図に示す如く液汁は －0.021 volt にて酸化波を生じ、その波の高さは 9 mm である。即ち標準ポーラログラムを基準として含有量は 3.3 mg% となる。アスコルビン酸の純度は 95 % であるから 3.14 mg% のビタミン C 含有量となる。

果肉は －0.022 volt にて酸化波を生じ、その波の高さは 10 mm である。即ち標準ポーラログラムを基準として 4.4 mg% の含有量となる。アスコルビン酸の純度は 95% であるから 4.18 mg% のビタミン C 含有量となる。

6. 洋梨罐詰（ラ、フランス）液汁及び果肉のポーラログラムは第 36 図及び第 37 図に示す如くで、液汁及び果肉共に何等の酸化波を生じない。依つて洋梨罐詰中には液汁及び果肉共にビタミン C を含有しない。

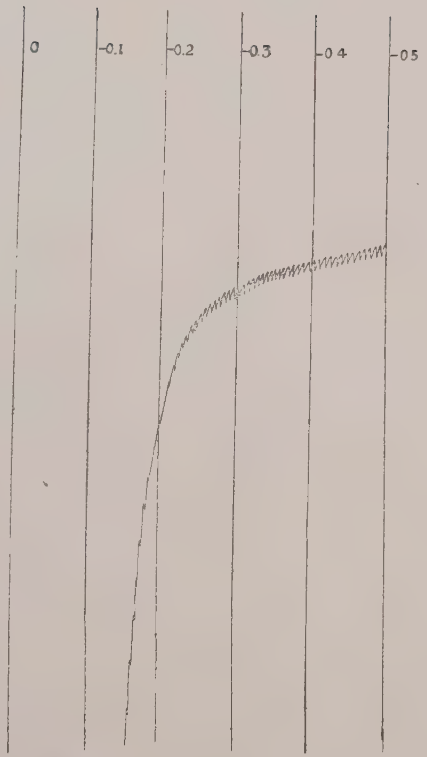
7. 桃罐詰（アーリー・エルバーター）液汁及び果肉のポーラログラムは第 38 図及び第 39 図に示す如く液汁は －0.018 volt にて酸化波を生じ、

第 36 図



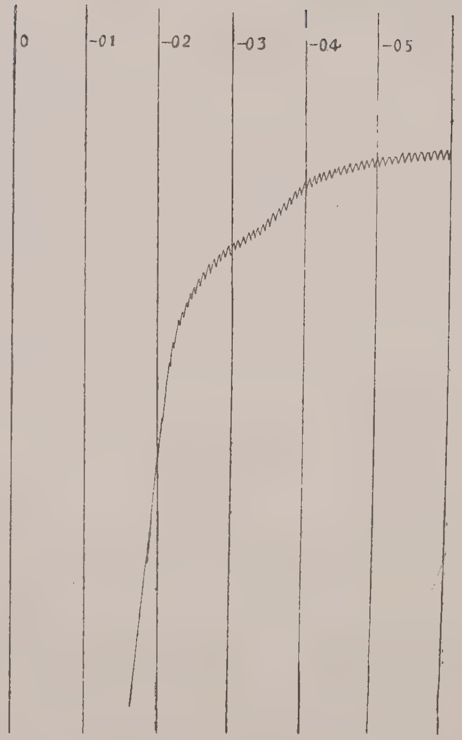
洋梨罐詰液汁 2 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの

第 37 図



洋梨罐詰果肉 10 g を pH 7.0 の燐酸緩衝液にて処理し 30 cc 液となし、その 5 cc 用う

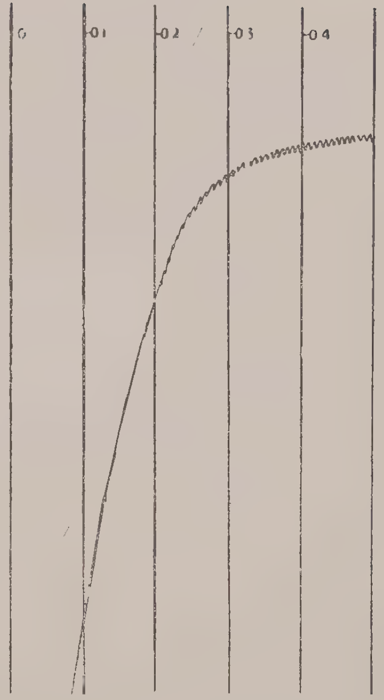
第 38 図



桃罐詰液汁 2 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの

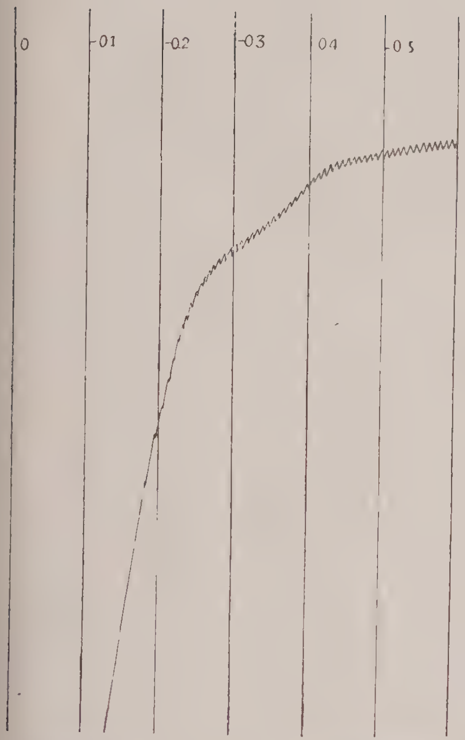
陽極電位 +0.393 volt
酸化電位 +0.018 volt

第 39 図



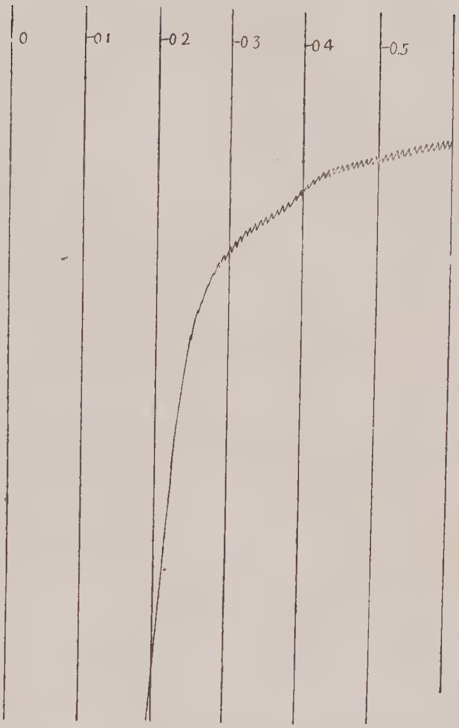
桃罐詰果肉 10 g を pH 7.0 の燐酸緩衝液にて処理し 30 cc となし、その 5 cc を用う

第 40 図



桃罐詰液汁 2 cc に pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
陽極電位 +0.402 volt
酸化電位 +0.015 volt

第 41 図



桃罐詰果肉 10 g を pH 7.0 の燐酸緩衝液にて処理し 30 cc となし、その 5 cc を用う
陽極電位 +0.402 volt
酸化電位 −0.003 volt

その波の高さは 10 mm である。即ち標準ポーラログラムを基準として含有量は 3.60 mg % となる。アスコルビン酸の純度は 95% であるから 3.42mg% のビタミン C 含有量となる。

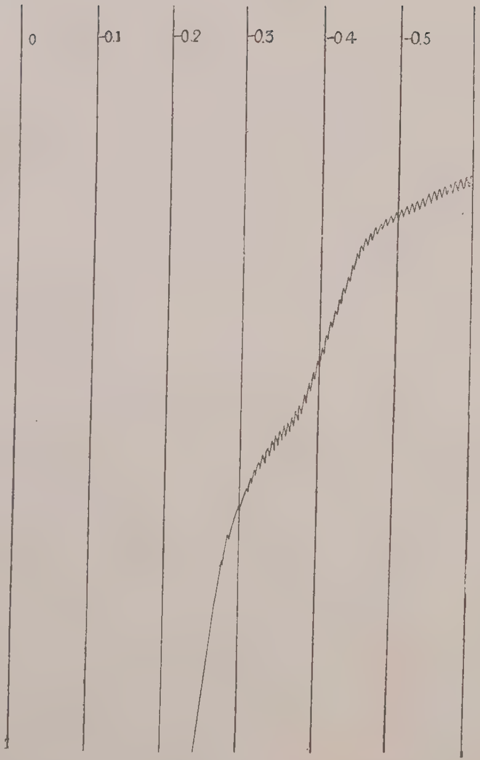
果肉は何等の酸化波を生じないから果肉中にはビタミン C は含有しない。

8. 桃罐詰（傳十郎）液汁及び果肉のポーラログラムは第 40 図及び第 41 図に示す如く液汁は +0.015 volt にて酸化波を生じ、その波の高さは 13 mm である。即ち標準ポーラログラムを基準として、含有量は 4.70 mg% となる。アスコルビン酸の純度が 95% であるから 4.47 mg% のビタミン C 含有量となる。

果肉は −0.003 volt にて酸化波を生じ、その波の高さは 10 mm である。即ち標準ポーラログラフを基準として 4.40 mg% の含有量となる。アスコルビン酸の純度が 95% であるから 4.18 mg% のビタミン C 含有量となる。

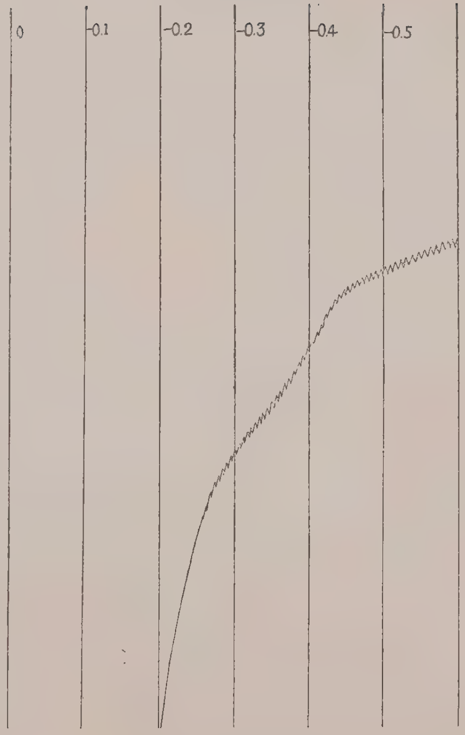
9. 栗罐詰液汁及び果肉のポーラログラムは第 42 図及び第 43 図に示す如く、液汁は −0.019 volt にて酸化波を生じ、その波の高さは 43 mm である。即ち標準ポーラログラムを基準とし

第 42 図



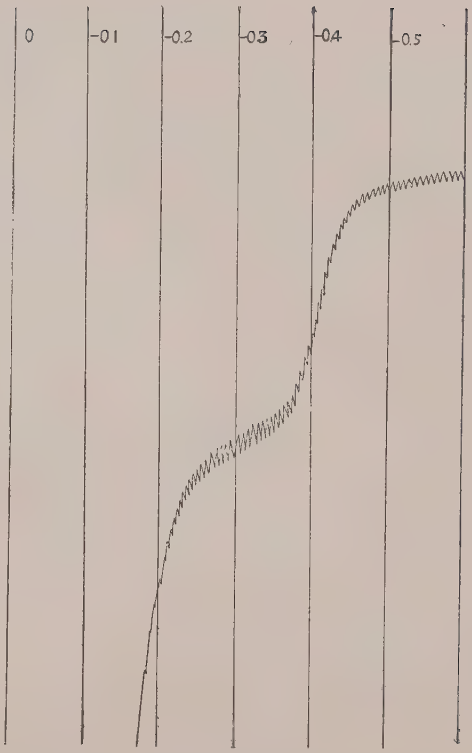
栗罐詰液汁 2 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 ＋0.393 volt
酸化電位 ＋0.019 volt

第 43 図



栗罐詰果肉 10 g を pH 7.0 の燐酸緩衝液にて処理し 30 cc となし、その 5 cc を用う
陽極電位 ＋0.393 volt
酸化電位 －0.017 volt

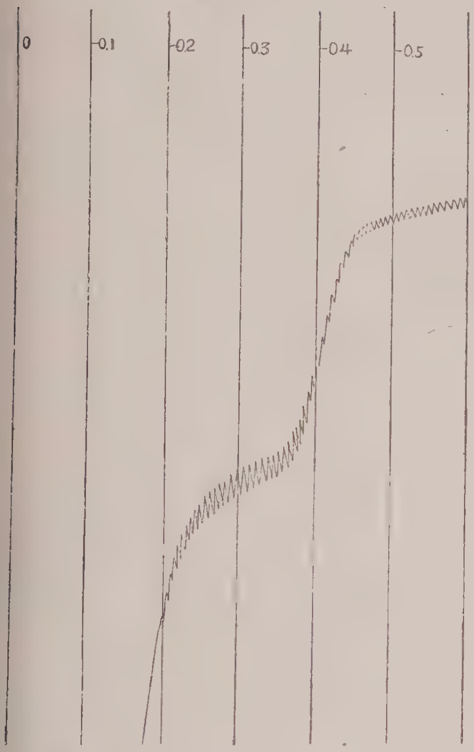
第 44 図



蜜柑罐詰（試料 A）の液汁 1 cc に pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
陽極電位 ＋0.391volt
酸化電位 －0.019volt

て、含有量は 15.55 mg% となる。アスコルビン酸の純度は 95% であるから 14.77 mg% のビタミン C 含有量となる。果肉は −0.017 volt にて酸化波を生じ、その波の高さは 20 mm である。即ち標準ポーラログラムを基準として含有量は 8.04 mg% となる。アスコルビン酸の純度が 95% であるから 7.64 mg% のビタミン C 含有量となる。

第 45 図

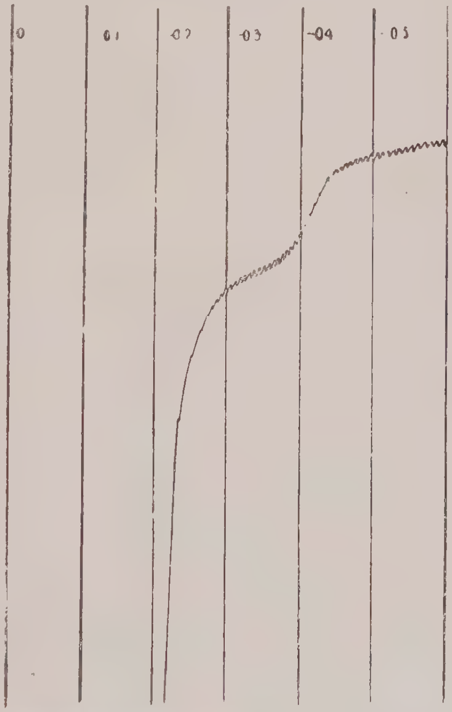


蜜柑罐詰（試料 A）の果肉 5 g を pH 7.0 の燐酸緩衝液にて処理し 25 cc となし、その 5 cc を用う
陽極電位 +0.388 volt
酸化電位 −0.028 volt

10. 蜜柑罐詰（試料 A）液汁及び果肉のポーラログラムは第 44 図及び第 45 図に示す如くで、液汁は −0.019 volt にて酸化波を生じ、その波の高さは 53 mm である。即ち標準ポーラログラムを基準として含有量は 38.70 mg% となる。アスコルビン酸の純度が 95% であるから 36.96 mg% のビタミン C 含有量となる。果肉は −0.027 volt にて酸化波を生じ、その波の高さは 56 mm である。即ち標準ポーラログラムを基準として含有量は 41.0 mg% となる。アスコルビン酸の純度が 95% であるから 38.95 mg% の含有量となる。

11. 蜜柑罐詰（試料 B）液汁及び果肉のポーラログラムは第 46 図及び第 47 図に示す如くで、液汁は −0.028 volt にて酸化波を生じ、その波の高さは 22 mm である。即ち標準ポーラログラムを

第 46 図

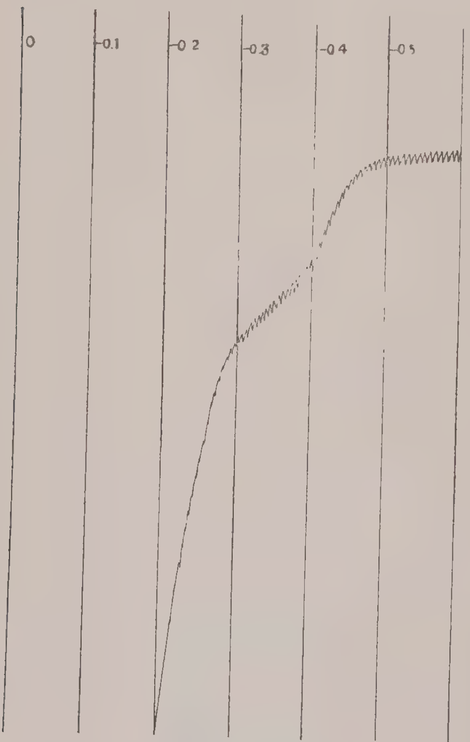


蜜柑罐詰（試料B）液汁 1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 +0.389 volt
酸化電位 −0.028 volt

基準として含有量は 16.1 mg% となる。アスコルビン酸の純度が 95% であるから 15.30 mg% のビタミン C 含有量となる。 果肉は −0.018 volt にて酸化波を生じ、その波の高さは 21 mm である。即ち標準ポーラログラムを基準として含有量は 15.4 mg% となる。アスコルビン酸の純度は 95% であるから 14.63 mg% のビタミン C 含有量となる。

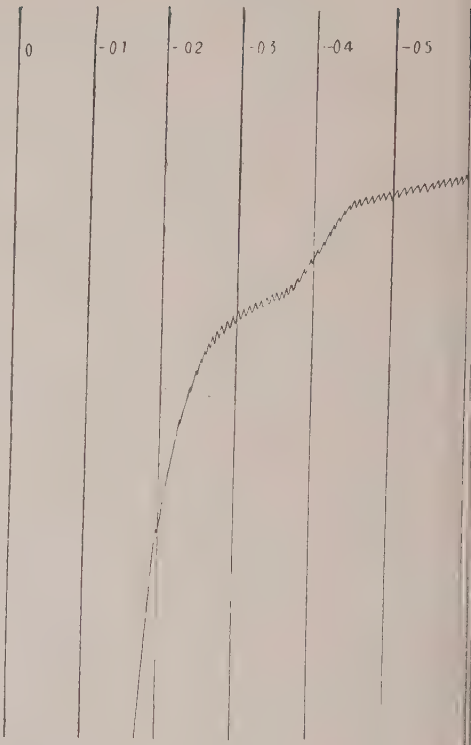
蜜柑罐詰は試料 A と B と 2 種類に就いて実験を行つたが試料 A は果肉の完全なもの、試料 B は果肉が崩れていたものである。ビタミン C の含有量は試料 A の方が遙に多く液汁、果肉共に試料 B の 2 倍以上であつた。

第 48 図



トマトジュース罐詰液汁 1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 +0.394 volt
酸化電位 −0.026 volt

第 47 図



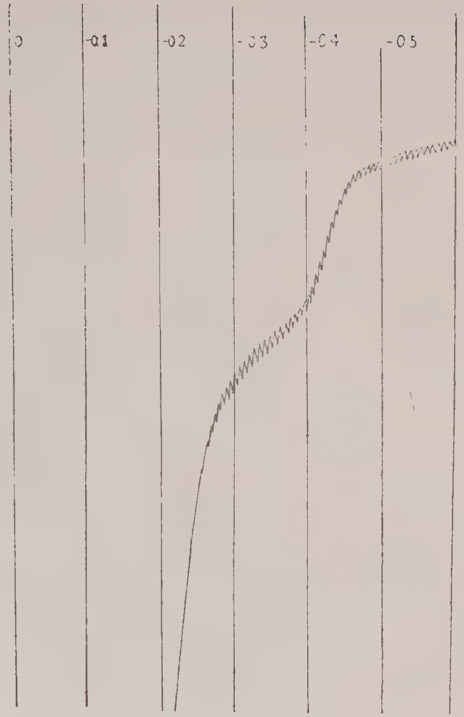
蜜柑罐詰（試料 B）果肉 5 g を pH 7.0 の燐酸緩衝液にて処理し 25 cc となし、その 5 cc を用う
陽極電位 +0.392 volt
酸化電位 −0.018 volt

12. トマトジュース罐詰のポーラログラムは 48 図に示す如く −0.026 volt にて酸化波を生じ、その波の高さは 25 mm である。

即ち標準ポーラログラムを基準として含有 は 18.40 mg% となる。アスコルビン酸の純度 95% であるから 17.48 mg% のビタミン C 有量となる。

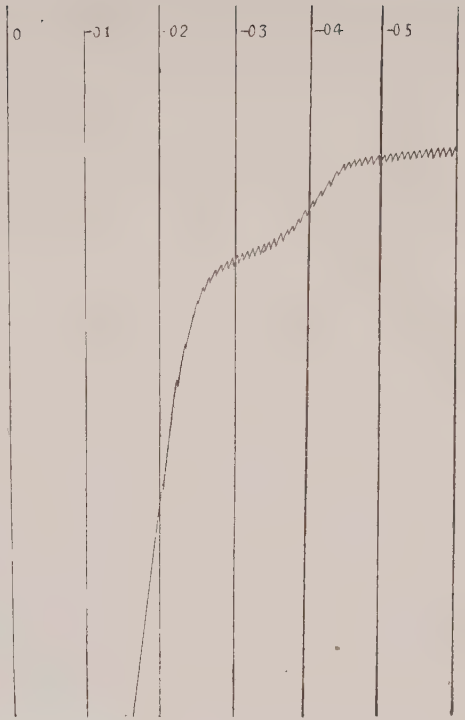
13. トマト罐詰（ソリツドパツク）液汁のポーラログラムは第 49 図に示す如く −0.042 volt にて酸化波を生じ、その波の高さは 34 mm である即ち標準ポーラログラムを基準として含有量は

第 49 図



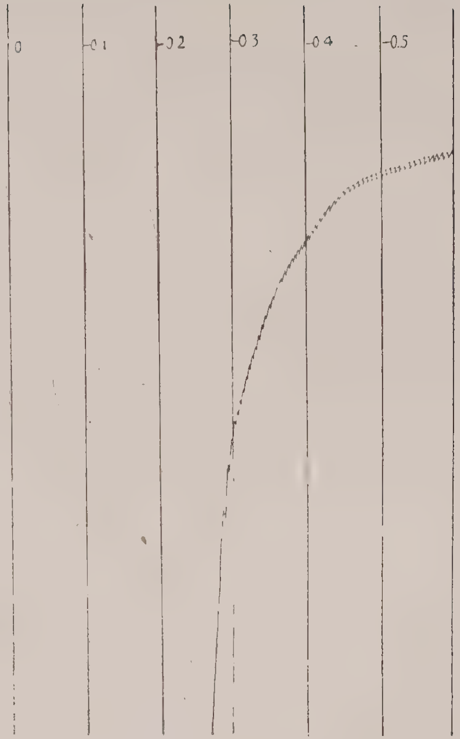
トマト罐詰液汁 1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 +0.388 volt
酸化電位 −0.042 volt

第 50 図



オレンジジュース罐詰液汁 1 cc に pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの
陽極電位 +0.380 volt
酸化電位 −0.030 volt

第 51 図



クリームスタイルコーン内容物 10 gを pH 7.0 の燐酸緩衝液にて処理し 30 cc となし、その 5 cc を用う
陽極電位 +0.383 volt
酸化電位 −0.027 volt

25.0 mg% となる。アスコルビン酸の純度は 95% であるから 23.75 mg% の含有量となる。

14. オレンジジュース罐詰液汁のポーラログラムは第 50 図に示す如く −0.030 volt にて酸化波を生じ、その波の高さは 16 mm である。即ち標準ポーラログラムを基準として含有量は 11.70 mg% となる。アスコルビン酸の純度は 95% であるから 11.12 mg% のビタミン C 含有量となる。

15. クリームスタイルコーン罐詰内容物のポーラログラムは第 51 図に示す如くである。−0.027 volt にて酸化波を生じ、その波の高さは 20 mm である。即ち標準ポーラログラムを基準として含有量は 8.82 mg% となる。アスコルビン酸の純度は 95% であるから 8.38 mg% のビタミン C 含有量となる。

16. 以上の結果を綜括して見ると第 5 表に示す如くである。

第 5 表

罐詰種類		製造年月		ポーラログラム図	試料溶液	酸化電位（ビタミンC）	波の高さ	ビタミンC含有量	ビタミンC含有量（アスコルビン酸の純度を95%として
		昭和年	月			volt	mm	mg%	mg%
枇杷	液汁	15	6	27	液汁 2 cc に液を加え 5 cc になせるもの	—	—	—	—
	果肉	15	6	28	果肉 30 g を液にて処理し 60 cc となし、その 5 cc を用う	—	—	—	—
林檎（ソリッドパック）	液汁	15	2	29	液汁 2 cc に液を加え 5 cc となせるもの	−0.020	6	4.40	4.18
	果肉	15	2	30	果肉 10 g を液にて処理し 30 cc となし、その 5 cc を用う	—	—	—	—
林檎ジュース		17	12	32	液汁 2 cc に液を加え 5 cc となせるもの	—	—	—	—
和梨（長十郎）	液汁	17	9	34	液汁 2 cc に液を加え 5 cc となせるもの	−0.020	9	3.30	3.14
	果肉	17	9	35	果肉 10 g を液にて処理し 30 cc となし、その 5 cc を用う	+0.022	10	4.40	4.18
洋梨（ラフランス）	液汁	17	11	36	液汁 2 cc に液を加え 5 cc となせるもの	—	—	—	—
	果肉	17	11	37	果肉 10 g を液にて処理し 30 cc となし、その 5 cc を用う	—	—	—	—
桃（アーリー、エルバーター）	液汁	14	8	38	液汁 2 cc に液を加え 5 cc となせるもの	+0.018	10	3.60	3.42
	果肉	14	8	39	果肉 10 g を液にて処理し 30 cc となし、その 5 cc を用う	—	—	—	—
桃（傳十郎）	液汁	17	8	40	液汁 2 cc に液を加え 5 cc となせるもの	+0.015	13	4.70	4.47
	果肉	17	8	41	果肉 10 g を液にて処理し 30 cc となし、その 5 cc を用う	−0.003	10	4.40	4.18
栗	液汁	不明		42	液汁 2 cc に液を加え 5 cc となせるもの	−0.019	43	15.55	14.77
	果肉	不明		43	果肉 10 g を液にて処理し 30 cc となし、その 5 cc を用う	−0.017	20	8.01	7.64

蜜柑（試料 A）	液汁	17	1	44	液汁 1 cc に液を加え 5 cc となせるもの	− 0.019	53	38.90	36.96
	果肉	17	1	45	果肉 5 g を液にて処理し 25 cc となし、その 5 cc を用う	− 0.027	56	41.00	38.95
蜜柑（試料 B）	液汁	不	明	46	液汁 1 cc に液を加え 5 cc となせるもの	− 0.028	22	16.10	15.30
	果肉	不	明	47	果肉 5 g を液にて処理し 25 cc となし、その 5 cc を用う	− 0.018	21	15.40	14.63
トマトジュース		17	7	48	液汁 1 cc に液を加え 5 cc となせるもの	− 0.026	25	18.40	17.48
トマト（ソリツドパツク）		17	8	49	液汁 1 cc に液を加え 5 cc となせるもの	− 0.042	34	25.00	23.75
オレンヂジュース		17	1	50	液汁 1 cc に液を加え 5 cc となせるもの	− 0.030	16	11.70	11.12
クリームスタイルコーン		17	8	51	内容物 10 g を液にて処理し 30 cc となし、その 5 cc を用う	− 0.027	20	8.82	8.38

備考　液は pH=7.0 の燐酸緩衝液を示す

要　　旨

1. 実験に用いた罐詰は枇杷、林檎、和梨、洋梨、桃(アーリー•エルバーター)、桃(傳十郎)、栗、密柑（試料 A)、蜜柑（試料 B)、トマトジュース、トマト（ソリツドパツク)、オレンジジュース、クリームスタイルコーンの 13 種及び林檎ジュース壜詰の 1 種である。

2. 罐詰中のビタミン C は果肉の完全な蜜柑罐詰（試料 A）に最も多く、その液汁中には 36.96 mg % を含み、崩肉蜜柑罐詰（試料 B）の 2 倍以上も含有している。即ち蜜柑罐詰に於ては内容果肉の完全なものの方が含有量が多い。トマト（ソリツドパツク）罐詰は 23.75 mg % を含みトマトジュース、栗、オレンジジュース、クリームスタイルコーン罐詰の順に含量は低下しているが尙相当のビタミン C を含有している。林檎、和梨、桃（アーリー • エルバーター)、桃(傳十郎）罐詰は極く少量を含有し、その量は 3～4 mg % である。枇杷罐詰及び林檎ジュース壜詰には含有しない。林檎及び桃（アーリー • エルバーター）罐詰は液汁には含有するが、果肉には存在しない。

3. 罐詰中のビタミン C は ＋0.020～－0.040 volt にて酸化波を生じた。

4. 林檎罐詰果肉は －0.162 volt にて、又林檎ジュース壜詰液汁は －0.123 volt にて多少の酸化波を生じた。これは他のものに比較して約 0.1 volt 以上その酸化電圧が異り、ビタミン C 以外の物質の存在によるものと思われるので、少量のアスコルビン酸を添加して見た処 2 段の酸化波を生じた。即ち －0.162 volt 及び －0.123 volt に生ずるものはビタミン C の酸化波ではない事が確められた。これによつて見るに林檎中には何等かビタミン C に附隨して而かもビタミン C に似た酸化圧を示すものの存在が予想される。

5. 本研究はビタミン C の還元型のみに就いて行つた結果である。

本研究に用いた罐詰は農林省農村工業指導所に於て製造されたものであつて、同所岩崎技師並びに農林省食品局技師横山博士の御盡力により提供されたものである。

第　4　章

ビタミン C の安定性に對する pH の影響に就いて

Baron(34) はアスコルビン酸は pH 7.0 までは酸性及び中性溶液では自酸化を起すことは少様であるがアルカリ性溶液では自酸化著しく、Keller(35) は金属触媒が存在しない時は酸素存在でも極めて安定で絶対的に純粋な水では固体の状態と同様であり換言すれば触媒の援助なしては酸素はアルコルビン酸に対して作用を及ぼさず、Mawson(36) は硝子器具で蒸溜した蒸水では比較的安定であり、篠原氏(37) は酸性溶液では自酸化しないと報告している。更に酸度ビタミン C 自酸化抑止作用に関してはZilva(38), Srinivasan(39), Kertestz(40), Sharp(41), Stieb,(42) 鈴木氏(43), 稲垣氏(44), 又最近ではアスコルビンの酸自酸化抑止に対して藤氏(45−51) の沢山の業績がある。尚水溶液中に銅鉄特に銅の如き重金属イオンが含まれているは其等金属イオンの接触作用に依り容易に酸化する。此事実は合成アスコルビン酸水溶液及び物材料中のアスコルビン酸溶液に就て既に証明されている。(55−75) 又一方之等金属特に銅のスコルビン酸接触酸化に対して、抑止作用を有する物質は多くの研究者に依つて多数擧げられ然も極めて廣範囲に亘つて居り、其等物質の抑止作用及び安定作用の機構は総てが充分に説明れていない現狀である。

依つて著者はビタミン C の安定性に対する水素イオン濃度及び硫酸銅を添加せる場合の影に就いてポーラログラフによる研究を行つた。

實 驗 の 部

本実験に関する諸條件はすべて第 1 章に記せるものと同様である。尚実験は 20° C に於てい、ポーラログラムは還元型アスコルビン酸の酸化波である。

1.　ビタミン C の安定性に対する pH の影響

各々に 0.01M のアスコルビン酸 0.1 cc を加え之に夫々 pH 7.0〜2.2 の枸櫞酸緩衝液を加え5 cc となせるものに就き、アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、2間後に於てポーラログラムを撮つた。その結果は第 6 表にアスコルビン酸の酸化波の高さ及化電位を、第 52 図にその酸化波の高さの変化を示し、第 53〜58 図にそのポーラログラムをした。（ポーラログラムに示す 1、2、3、4、5、6 は夫々アスコルビン酸添加の直後、2 時間4 時間後、6 時間後、24 時間、48 時間後に於ける還元型アスコルビン酸の酸化波を示す。以同様。アスコルビン酸の濃度は 2.0×10^{-4} である。）

第　6　表

pH 7.0〜2.2 に於けるアスコルビン酸の酸化波の高さ及び酸化電位

時間 pH	直　　後	2 時 間 後	4 時 間 後	8 時 間 後	24 時 間 後
	mm	mm	mm	mm	mm
7.0	24	11	6	4	—
6.0	29	21	16	11	3
5.0	31	25	21	16	5
4.0	31	26	23	18	8
3.0	32	30	28	26	12
2.2	32	31	29	28	21

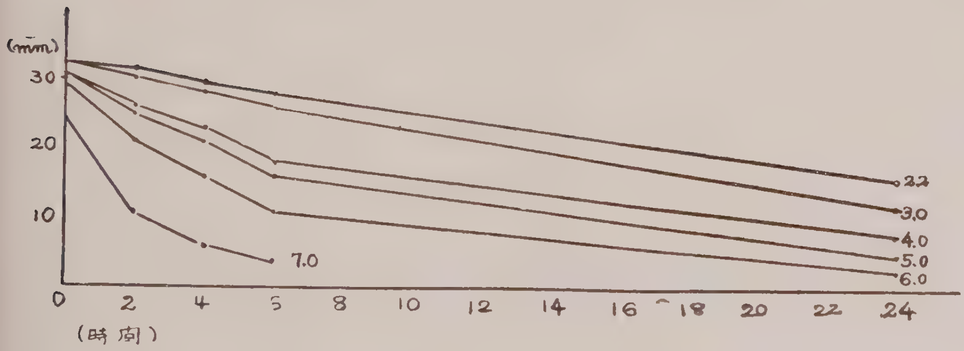
酸　化　電　位

（1 規定甘汞電極を基準）

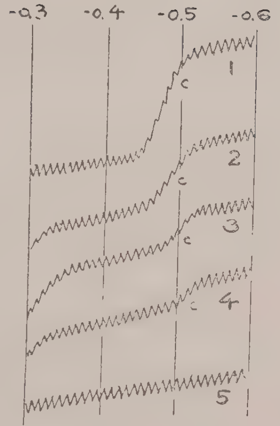
	volt	volt	volt	volt	volt
7.0	−0.059	−0.055	−0.052	−0.057	—
6.0	−0.024	−0.024	−0.027	−0.026	−0.029
5.0	+0.017	+0.013	+0.016	+0.018	+0.018
4.0	+0.087	+0.078	+0.082	+0.088	+0.081
3.0	+0.121	+0.128	+0.115	+0.128	+0.136
2.2	+0.171	+0.178	−0.170	+0.0_8	+0.201

第　25　図

pH 7.0—2.2 に於けるアスコルビン酸の酸化波の高さの變化

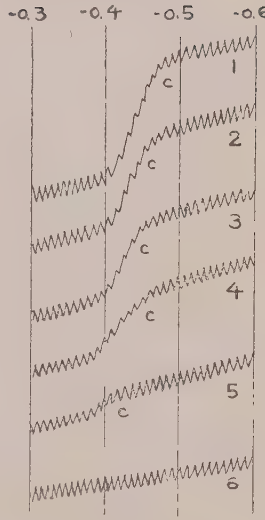


第 53 図



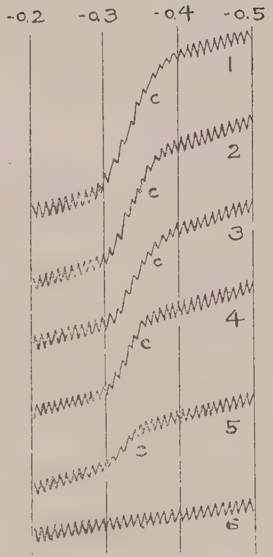
0.01 M アスコルビン酸 0.1cc に
pH 7.0 の燐酸緩衝液を加えて 5cc
となせるもの
アスコルビン酸の濃度は
2.0×10^{-4}M
酸化電位 1. −0.059 volt（1 規定
甘汞電極を基準）
2. −0.055 〃（〃）
3. −0.052 〃（〃）
4. −0.057 〃（〃）

第 54 図



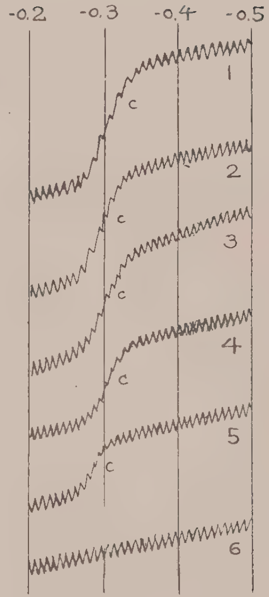
0.01 M アスコルビン酸 0.1cc に
pH 6.0 の燐酸緩衝液を加えて 5cc
となせるもの
アスコルビン酸の濃度は
2.0×10^{-4}M
酸化電位 1. −0.024 volt（1 規定
甘汞電極を基準）
2. −0.024 〃（〃）
3. −0.027 〃（〃）
4. −0.026 〃（〃）
5. −0.029 〃（〃）

第 55 図



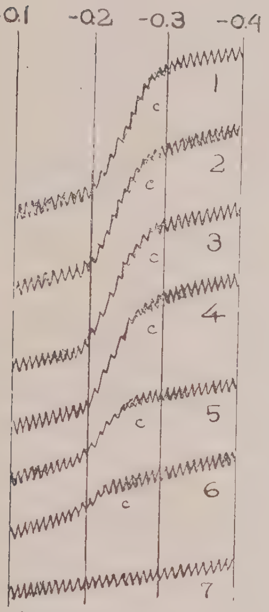
0.01 M アスコルビン酸 0.1cc に
pH 5.0 の燐酸緩衝液を加えて 5cc
となせるものアスコルビン酸の濃
度は 2.0×10^{-4}M
酸化電位 1. +0.017 volt（1 規定
甘汞電極を基準）
2. +0.013 〃（〃）
3. +0.016 〃（〃）
4. +0.018 〃（〃）
5. +0.018 〃（〃）

第 56 図



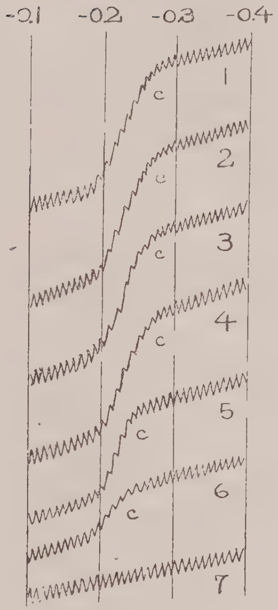
0.01 M アスコルビン酸 0.1cc に
pH 4.0 の燐酸緩衝液を加えて 5cc
となせるものアスコルビン酸の濃
度は 2.0×01^{-4}M
酸化電位 1. +0.087 volt（1 規定
甘汞電極を基準）
2. +0.078 〃（〃）
3. +0.082 〃（〃）
4. +0.088 〃（〃）
5. +0.081 〃（〃）

第 57 図



0.01 M アスコルビン酸 0.1cc に pH 3.0 の燐酸緩衝液を加えて5ccとなせるもの
アスコルビン酸の濃度は 2.0×10⁻⁴M
酸化電位 1. +0.121 volt （1規定甘汞電極を基準）
2. +0.128 〃 （ 〃 ）
3. +0.115 〃 （ 〃 ）
4. +0.128 〃 （ 〃 ）
5. +0.136 〃 （ 〃 ）

第 58 図



0.01 M アスコルビン酸 0.1cc に pH 2.2 の燐緩衝液を加えて 5cc となせるもの
アスコルビン酸の濃度は 2.0×10⁻⁴M
酸化電位 .1 +0.171 volt （1規定甘汞電極を基準）
2. +0.178 〃 （ 〃 ）
3. +0.170 〃 （ 〃 ）
4. +0.203 〃 （ 〃 ）
5. +0.201 〃 （ 〃 ）

2. 前記 1 の場合に硫酸銅を添加せる時の影響

Euler(63) は溶液中に微量の銅の存在するときは酸素による酸化を著しく促進する。酸化されたものは勿論ビタミン C としての生理作用を消滅することを報告し、W.Klodt 及び Stieb(64) はビタミン C の酸化に対して、銅は強力なる触媒作用を呈することを示し、稲垣氏(65) は種々の重金属中銅イオンに依る酸化は最大であると報告している。依つて著者は前記各 pH のアスコルビン酸溶液に硫酸銅を加えた場合の影響に就いて実験を試みた。

即ち前記各 pH の溶液に夫々 1.0×10^{-7}M の硫酸銅を加え、液の総量は各 pH の枸櫞酸緩衝液にて 5cc となせるものに就き（アスコルビン酸の濃度は 2.0×10^{-4}M）1 の場合と同様に時間の経過と共にポーラログラムを撮つた。その結果は第 7 表にアスコルビン酸の酸化波の高さ及び酸化電位を、第 59 図に酸化波の高さの変化を示し、第 60～65 図にそのポーラログラムを示した。

第 7 表

pH 7.0～2.2 に於いて $CuSO_4$ を添加せる場合のアスコルビン酸の酸化波の高さ及び酸化電位

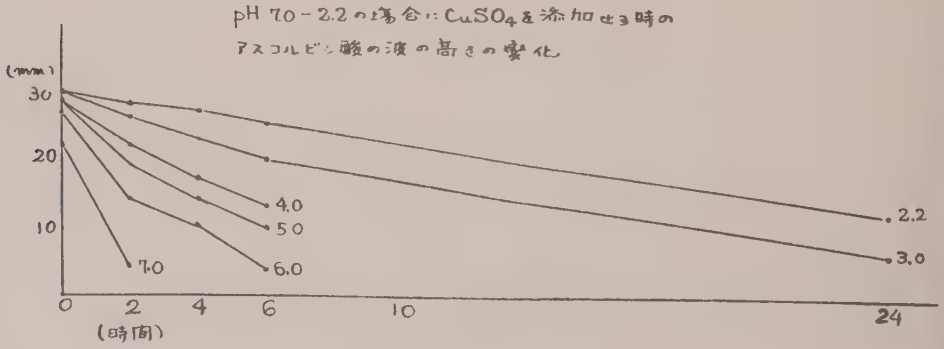
Hp ＼ 時間	直後	2 時間後	4 時間後	6 時間後	2 4 時間後
	mm	mm	mm	mm	mm
7.0	22	4	—	—	—
6.0	27	14	10	4	—
5.0	29	19	14	10	—
4.0	29	22	17	13	—
3.0	30	26	23	20	6
2.2	30	28	27	25	12

酸 化 電 位

（1規定甘汞電極を基準）

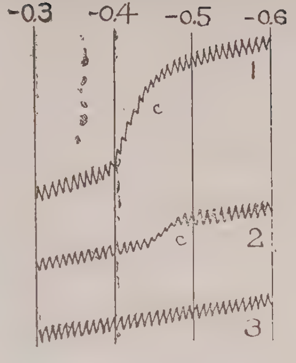
	volt	volt	volt	volt	volt
7.0	−0.039	−0.048	—	—	—
6.0	−0.004	−0.008	−0.002	−0.005	—
5.0	+0.041	+0.037	+0.033	+0.047	—
4.0	+0.082	+0.086	+0.080	+0.080	—
3.0	+0.120	+0.126	+0.125	+0.125	+0.133
2.2	+0.160	+0.161	+0.165	+0.165	+0.162

第 58 図



pH 7.0 − 2.2 の場合に $CuSO_4$ を添加せる時の
アスコルビン酸の波の高さの変化

第 60 図



0.01 **M** **アスコルビン酸** 0.1cc に 1.0×10^{-3}**M** $CuSO_4$ 0.1ccを 加え **pH** 7.0 の燐酸緩衝液にて 5cc となせるもの

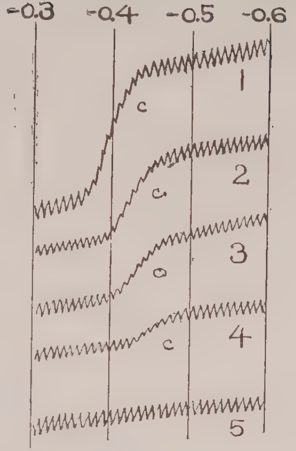
アスコルビン酸の濃度は

2.0×10^{-4}M

酸化電位 1. −0.039 volt（1 規定甘汞電極を基準）

2. −0.018 volt（ 〃 ）

第 61 図



0.01 M アスコルビン酸 0.1cc に 1.0×10^{-3}M $CuSO_4$ 0.1cc を加え **pH** 6.0 液酸緩衝液にて 5cc となせるのもの

アスコルビン酸の濃度は

2.0×10^{-4}**M**

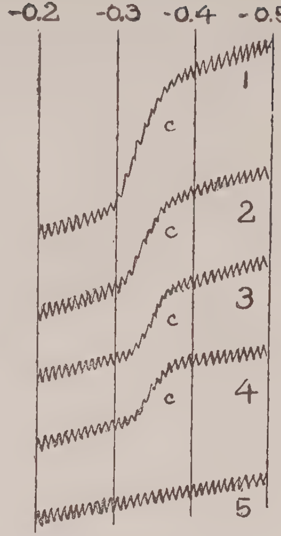
酸化電位 1. −0.004 volt（1 規定甘汞電極を基準）

2. −0.003 〃（ 〃 ）

3. −0.002 〃（ 〃 ）

4. −0.005 〃（ 〃 ）

第 62 図



0.01 **M** アスコルビン酸 0.1cc に 1.0×10^{-3} M $CuSO_4$ 0.1cc を加え **pH** 5.0 の燐酸緩衝液を加えて 5cc となせるもの

アスコルビン酸の濃度は

2.0×10^{-4}**M**

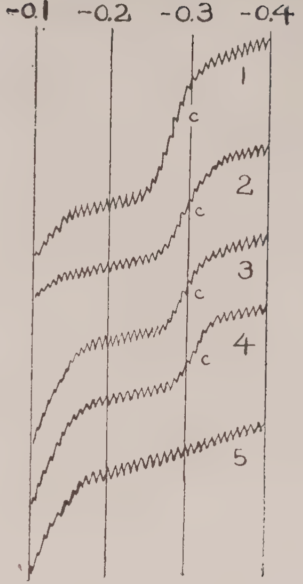
酸化電位 1. +0.041 volt（1 規定甘汞電極を基準）

2. +0.037 〃（ 〃 ）

3. +0.033 〃（ 〃 ）

4. +0.047 〃（ 〃 ）

第 63 図



0.01 **M** アスコルビン酸 0.1cc に 1.0 × 10^{-3}**M** $CuSo_4$ 0.1cc を加え **pH** 4.0 の燐酸緩衝液にて 5cc となせるもの

アスコルビン酸の濃度は

2.0×10^{-4}**M**

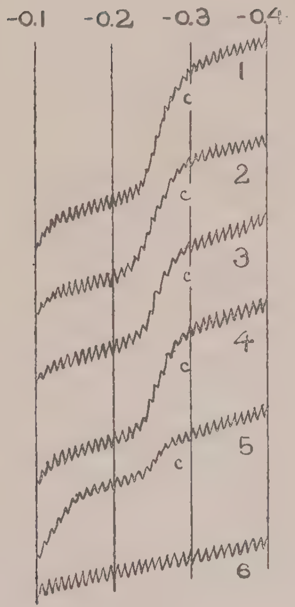
酸化電位 1. +0.082 volt（1 規定甘汞電極を基準）

2. +0.036 〃（ 〃 ）

3. +0.080 〃（ 〃 ）

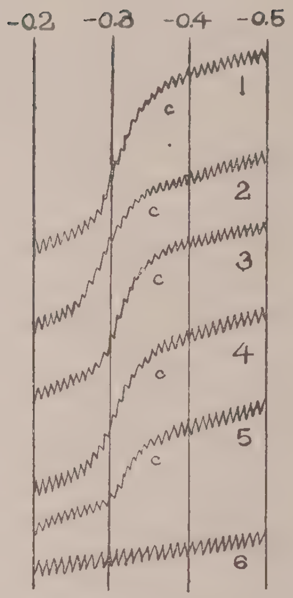
4. +0.080 〃（ 〃 ）

第 64 図



0.01 M アスコルビン酸 0.1cc に 1.0×10^{-3}M
CuSO$_4$ 0.1cc を加え pH 3.0 の燐酸緩衝液
にて 5cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4}
酸化電位 1. +0.120 volt（1規定甘汞電極を基準）
2. +0.126 〃 （〃）
3. +0.125 〃 （〃）
4. +0.125 〃 （〃）
5. +0.133 〃 （〃）

第 65 図



0.01 M アスコルビン酸 0.1cc に 1.0×10^{-2}M
CuSO$_4$ 0.1cc を加え pH 2.2 の燐酸緩衝液
にて 5cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4}M
酸化電位 1. +0.160 volt（1規定甘汞電極を基準
2. +0.161 〃 （〃）
3. +0.165 〃 （〃）
4. +0.165 〃 （〃）
5. +0.162 〃 （〃）

3. 硫酸銅を添加せざる場合と、添加せる場合との比較

硫酸銅を加えざるもののアスコルビン酸添加直後のポーラログラムの酸化波の高さを 100 %
として、硫酸銅を加えたるものとその残存率を比較して見ると、第 8 表及び第 66 図に示す如く
硫酸銅を加えざるものは pH 7.0 にては 6 時間後に於て 17 % 残存しているが、硫酸銅を加え
ものは 6 時間後に於て皆無である。しかし酸性となるに従い、硫酸銅を添加せざるものも、添
せるものも、何れも安定性を増加し、硫酸銅を加えたものに於て pH 2.2 の場合 6 時間後迄は
酸銅を加えざるものより 10 % 位の減少であつて、24 時間後に於ても 37 % を残存し、硫酸銅
加えざるものの半分以上を保有している。要するに酸性となるに従い安定性は増加し、硫酸銅
加えた場合に於ても酸性となる程安定性となり接触的酸化を或程度防止することが出來る。
Zilva(66), Mawson(67) 等はレモン果汁の抗壊血効力の安定な原因は pH 2.2 位の高度の酸性

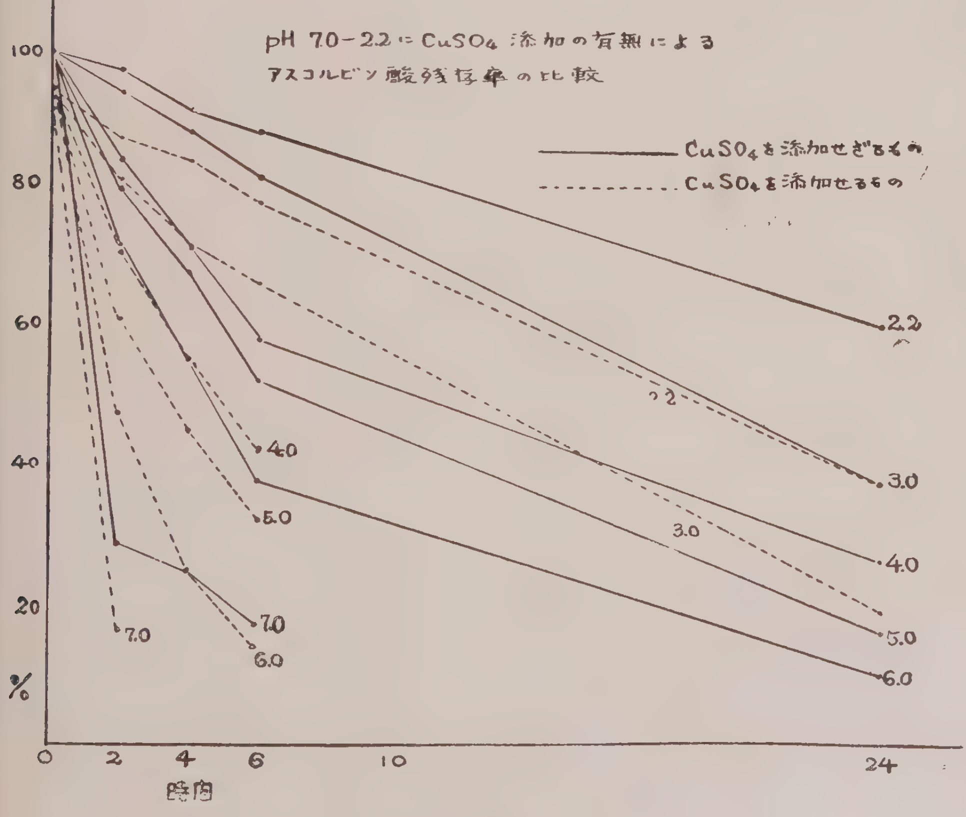
あると述べ、又稲垣氏(8)も温州蜜柑果汁中のビタミンCの安定性は非常に高度なものにして、酸化触媒使用の場合に於てさえも40±1°Cに7時間放置しても殆んど損失は認められずとあるのも、その pH が相当に酸性であるためにその安定性に対して有効であることが一つの原因であると考えられる。

第 8 表

pH 7.0 2.2 に $CuSO_4$ 添加の有無によるアスコルビン酸残存率の比較

時間 / pH	$CuSO_4$ を加えざるもの					$CuSO_4$ を加えたるもの				
	直後	2時間後	4時間後	6時間後	24時間後	直後	2時間後	4時間後	6時間後	24時間後
	%	%	%	%	%	%	%	%	%	%
7.0	100	29	25	17	—	92	17	—	—	—
6.0	100	72	55	38	10	93	48	25	14	—
5.0	100	80	65	52	16	94	61	45	32	—
4.0	100	84	71	58	26	94	71	55	42	—
3.0	100	94	88	81	37	94	81	72	66	19
2.2	100	97	91	88	60	94	87	84	78	37

第 66 図



要　　　旨

1. 2.0×10^{-4}Mのアスコルビン酸の濃度に於て、pH 7.0～2.2 に於て、酸性となる程アスコルビン酸の自酸化に対する安定性は増大する。

2. 硫酸銅を加えた場合に於ても、同様に酸性となる程安定性は増大する。（硫酸銅を加えざるものと比較して多少劣る）即ち酸度の高い程銅の接触酸化に対し抑止作用を有す。

第　5　章

ビタミン C の安定性に対する枸櫞酸の効果

ビタミン C の安定性に関する酸類の影響に就いては Zilva(69), Mawson(70) はその効果が pH 2.2 位の高度の酸性なるためレモン果汁は安定であるとなし、Barron(71), Gosh(72) King(73) 等は燐酸、硼酸、枸櫞酸を緩衝液基質に選んで研究を行い、又醋酸、フタール酸枸櫞酸を使用したものに海老原(74), 篠原氏(75) 等がある。又佐木、中山、岡、武石氏(76) 等は枸櫞酸は却つて酸化を促進するもので何等安定性に対して効果なしと報告している。タンニン酸の効果に就いては Srinivasan(77), Nair(78) 及び二國、辰巳氏(79) 等の報告がある。又酸構造との関係に就て行われたものに渡辺氏(80), Stohecker(81), 及び兒玉氏(80) 等の報告がある。渡辺氏はビタミン C の安定度は pH の概念だけでは説明出来ないとし、又 Stohecker は OH の多少にて酸化抑止作用に差違を生ずると言い、兒玉氏は酸類と化学構造との関係を N/10 の場合に就て報告し、一種の制約を発表した。更に最近稲垣氏(65) は有機酸及び無機酸の一部に就て、一定の実験條件及び酸構造、濃度、pH に於て酸類と酸化速度との関係を検討し更に銅イオン添加の有無が抑止作用の強弱に対し如何なる差異を生ずるかを検し、その結果各有機酸又は無機酸の種類による酸化抑止作用力の差は酸の構造並びに濃度によつて左右され pH の影響は殆んど認められずとなし、触媒としての銅イオンの添加の有無によりて、一部の酸類にあつては、その抑止作用力の順位に変更がなされ、即ちメタ燐酸及び多塩基酸にあつては常に最上位にしてその順位は変更を見ず、一塩基飽和酸にあつては順位の変更を認めると称している。此処に於て著者は第1 章に於て pH 7.0 の燐酸緩衝液を用いた場合、枸櫞酸若しくは枸櫞酸加里を加えなければ一定の高さの酸化波を有するポーラログラムが得られなかつた。それで数種の有機酸及びそれらの塩類に就き、その安定性をポーラログラフ的に研究し、先づ第一にビタミン C の安定性に対する枸櫞酸の効果及び之に硫酸銅を加えた場合の影響に就て実験を試みた次第である。

實驗の部

実験に関するすべての條件は第1章と同様である。

1. ビタミンCの安定性に対する枸櫞酸の効果

各々に0.01Mのアスコルビン酸溶液0.1ccを加え、之に0.1Mの枸櫞酸を夫々0.1、0.5、1.0、2.0、3.0、4.0、4.9ccを加え、更にpH 7.0の燐酸緩衝液を加えて5ccとなし（但し枸櫞酸4.9cc添加の場合には燐酸緩衝液を加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つた。その結果第9表にアスコルビン酸の酸化波の高さ及びその酸化電位を、第67図にその酸化波の高さの変化を示し、第68図～第74図にそのポーラログラムを示した（図の1、2、3、4、5、6は夫々アスコルビン酸添加の直後、2時間後、4時間後、6時間後、24時間後、48時間後に於けるアスコルビン酸の酸化波を示す。アスコルビン酸の濃度は2.0×10^{-4}Mである。以下同様）

第9表

枸櫞酸添加によるアスコルビン酸の酸化波の高さ及び酸化電位

枸櫞酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
cc		mm	mm	mm	mm	mm
0.1	6.4	24	13	5	—	—
0.5	6.0	30	24	14	12	—
1.0	5.8	30	25	17	15	—
2.0	5.0	31	30	29	27	13
3.0	3.2	31	30	29	27	15
4.0	2.4	32	31	30	29	18
4.9	2.0	32	31	30	30	18

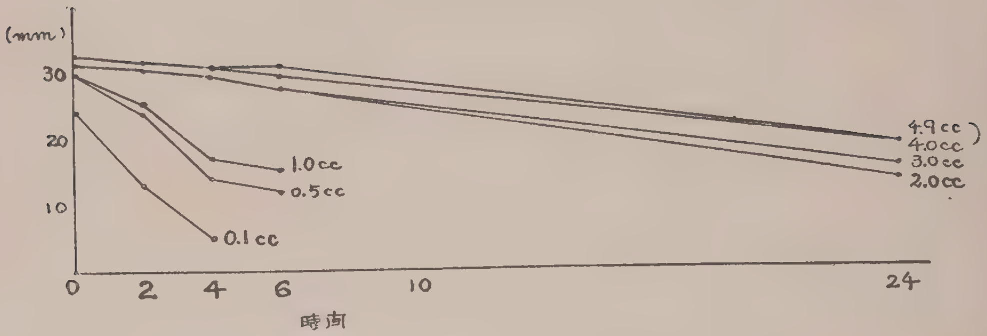
酸化電位

（1規定甘汞電極を基準）

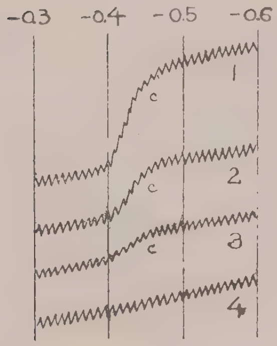
cc		volt	volt	volt	volt	vslt
0.1	6.4	+0.031	+0.061	+0.054	—	—
0.5	6.0	+0.106	+0.106	+0.109	+0.103	—
1.0	5.8	+0.168	+0.161	+0.164	+0.173	—
2.0	5.0	+0.228	+0.236	+0.224	+0.233	+0. 24
3.0	3.2	+0.161	+0.164	+0.165	+0.160	+0.169
4.0	2.4	+0.181	+0.180	+0.175	+0.169	+0.179
4.9	2.0	+0.181	+0.184	+0.180	+0.180	+0.179

第 67 図

枸櫞酸添加によるアスコルビン酸の
酸化波の高さの変化

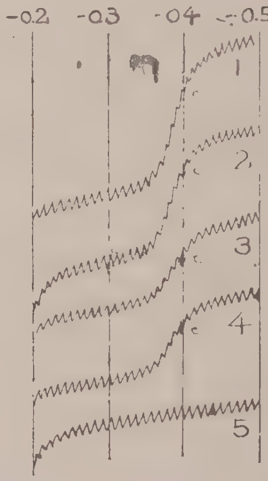


第 68 図



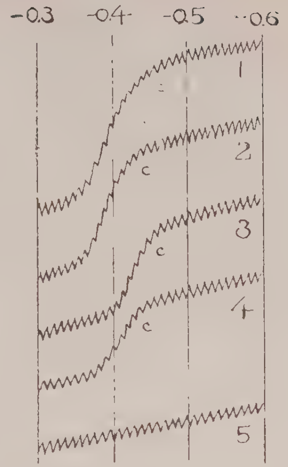
0.01M アスコルビン酸 0.1cc に 0.1M 枸櫞酸 0.1cc を加え pH 7.0 の燐酸緩衝液を加えて 5cc となせるもの
アスコルビン酸の濃度は 2.0×10⁻⁴M
酸化電位 1. ＋0.061 volt (1規定甘汞電極を基準)
2. ＋0.061 〃 (〃)
3. ＋0.054 〃 (〃)

第 69 図



0.01M アスコルビン酸 0.1cc に 0.1M 枸櫞酸 0.5cc を加え pH 7.0 の燐酸緩衝液を加えて 5cc となせるもの
アスコルビン酸の濃度は 2.0×10⁻⁴M
酸化電位 1. ＋0.106 volt (1規定甘汞電極を基準)
2. ＋0.160 〃 (〃)
3. ＋0.109 〃 (〃)
4. ＋0.103 〃 (〃)

第 70 図

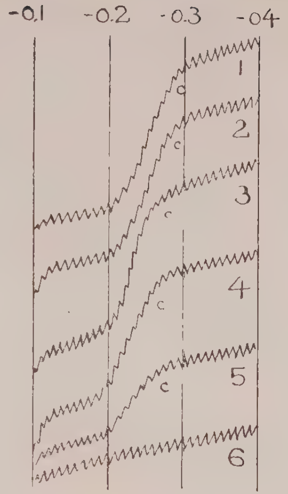


0.01 **M** アスコルビン酸 0.1cc に 0.1 **M** 枸櫞酸 1.0cc を加え pH 7.0 の燐酸緩衝液を加えて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^-4^M

酸化電位 1. +0.168 volt（1 規定甘汞電極を基準）
2. +0.161 〃（〃）
3. +0.164 〃（〃）
4. +0.173 〃（〃）

第 71 図

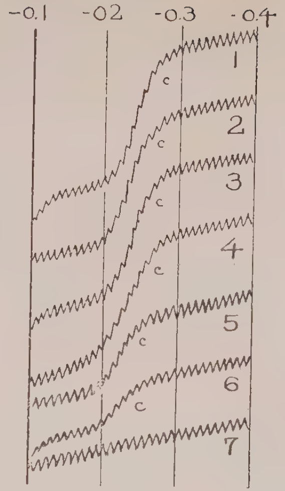


0.01 **M** アスコルビン酸 0.1cc に 0.1 **M** 枸櫞酸 2.0cc を加え pH 7.0 の燐酸緩衝液を加えて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^-4^M

酸化電位 1. +0.228 volt（1 規定甘汞電極を基準）
2. +0.236 〃（〃）
3. +0.224 〃（〃）
4. +0.233 〃（〃）
5. +0.224 〃（〃）

第 72 図

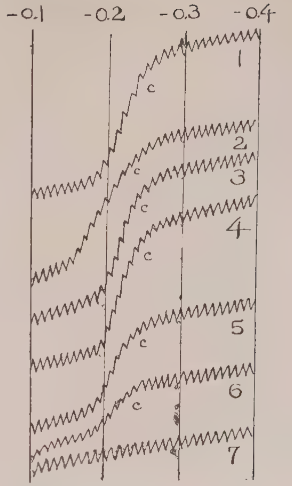


0.01 **M** アスコルビン酸 0.1cc に 0.1 **M** 枸櫞酸 3.0cc を加え pH 7.0 の燐酸緩衝液を加えて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^-4^M

酸化電位 1. +0.161 volt（1 規定甘汞電極を基準）
2. +0.164 〃（〃）
3. +0.165 〃（〃）
4. +0.160 〃（〃）
5. +0.169 〃（〃）

第 73 図

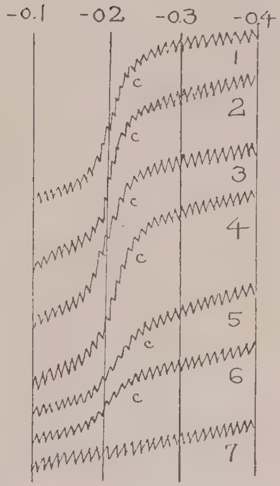


0.01 **M** アスコルビン酸 0.1cc に 0.1 **M** 枸櫞酸 4.0cc を加え pH 7.0 の燐酸緩衝液を加えて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^-4^M

酸化電位 1. +0.181 volt（1 規定甘汞電極を基準）
2. +0.180 〃（〃）
3. +0.175 〃（〃）
4. +0.169 〃（〃）
5. +0.179 〃（〃）

第 74 図



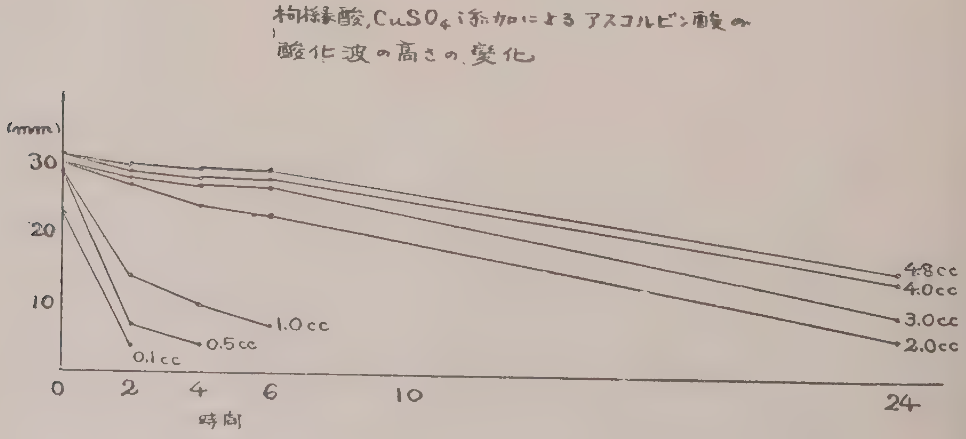
0.01 **M** アスコルビン酸 0.1cc に
0.1 **M** 枸櫞酸 1.9cc を加えたるもの
アスコルビン酸の濃度は
2.0×10^{-1}M
酸化電位 1. ＋0.181 volt（1規定甘
汞電極を基準）
2. ＋0.184 〃（ 〃 ）
3. ＋0.180 〃（ 〃 ）
4. ＋0.180 〃（ 〃 ）
5. ＋0.179 〃（ 〃 ）

2. 前記 1 の場合に硫酸銅を添加せる時の影響

第 4 章 2 の場合と同様に銅イオンを加えた時、その接触的酸化抑止の効果を見るため前記枸櫞酸添加の各液に夫々 1.0×10^{-5}M′ の硫酸銅溶液 0.1cc 宛を加え液の総量を燐酸緩衝液にて 5cc となし（但し前記枸櫞酸 4.9cc 添加のものは此の場合 4.8cc となし、燐酸緩衝液は加えなかつた。）前記同様ポーラログラムを撮つた。

その結果第 10 表にアスコルビン酸の酸化波の高さ及び酸化電位を、第 75 図にその酸化波の高さの変化を示し、第 76 図〜第 82 図にそのポーラログラムを示す。

第 75 図



第 10 表

枸櫞酸に $CuSO_4$ を添加せる場合のアスコルビン酸の酸化波の高さ及び酸化電位

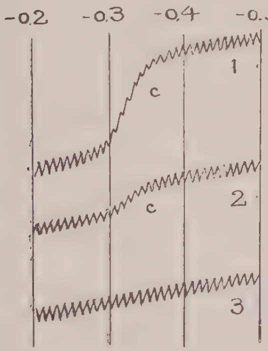
枸櫞酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
cc		mm	mm	mm	mm	mm
0.1	6.4	23	4	—	—	—
0.5	6.0	29	7	4	—	—
1.0	5.8	29	14	10	7	—
2.0	5.0	30	27	24	23	6
3.0	3.2	30	28	27	27	9
4.0	2.4	31	29	28	28	14
4.8	2.0	31	30	29	29	15

酸化電位

（1規定甘汞電極を基準）

cc		volt	volt	volt	volt	volt
0.1	6.4	−0.021	−0.020	—	—	—
0.5	6.0	+0.013	+0.014	+0.011	—	—
1.0	5.8	+.0093	+0.030	+0.088	+0.098	—
2.0	5.0	+0.140	+0.138	+0.142	+0.137	+0.140
3.0	3.2	+0.160	+0.165	+0.162	+0.167	+0.170
4.0	2.4	+0.170	+0.165	+0.167	+0.172	+0.175
4.8	2.0	+0.190	+0.190	+0.187	+0.182	+0.185

第 76 図

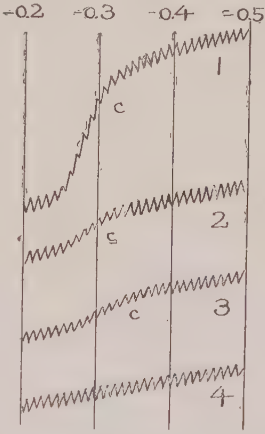


0.01 M アスコルビン酸 0.1cc に 1.0×10^{-3}M $CuSO_4$ 0.1cc を加え更に 0.1M 枸櫞酸を加え pH 7.0 の燐酸緩衝液を加えて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4}M

酸化電位 1. −0.021 volt（1規定甘汞電極を基準）
2. −0.020 〃（〃）

第 77 図

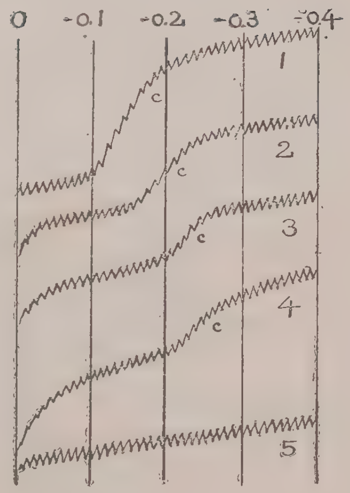


0.01 M アスコルビン酸 0.1cc に 1.0×10^{-3}M $CuSO_4$ 0.1cc を加え更に 0.1M 枸櫞酸 0.5 cc を加え pH 7.0 の燐酸緩衝液を加えて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4}M

酸化電位 1. +0.013 volt（1規定甘汞電極を基準）
2. +0.014 〃（〃）
3. +0.011 〃（〃）

第 78 図

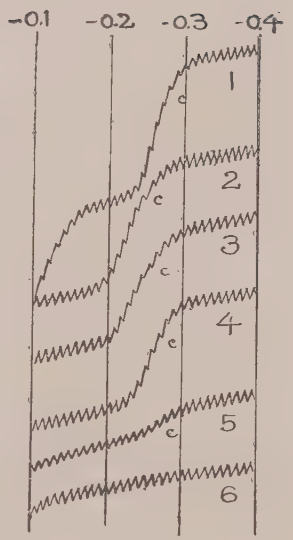


0.01 M アスコルビン酸 0.1cc に 1.0×10^{-5}M $CuSO_4$ 0.1cc を加え更に 0.1 M 枸櫞酸 1.0cc を加え pH 7.0 の燐酸緩衝液にて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4}M

酸化電位 1. +0.090 volt（1 規定甘汞電極を基準）
2. +0.090 〃（〃）
3. +0.088 〃（〃）
4. +9.098 〃（〃）

第 79 図

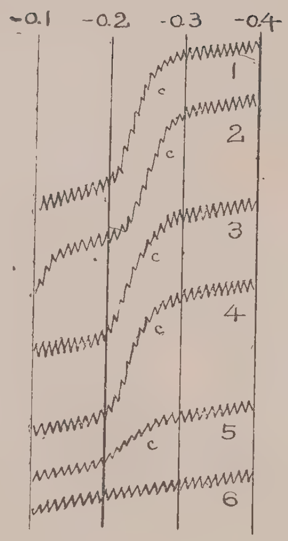


0.01 M アスコルビン酸 0.1cc に 1.0×10^{-5}M $CuSO_4$ 0.1cc を加え更に 0.1M 枸櫞酸 2.0cc を加え pH 7.0 の燐酸緩衝液にて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4}M

酸化電位 1. +0.140 volt（1 規定甘汞電極を基準）
2. +0.138 〃（〃）
3. +0.142 〃（〃）
4. +0.137 〃（〃）
5. +0.140 〃（〃）

第 80 図

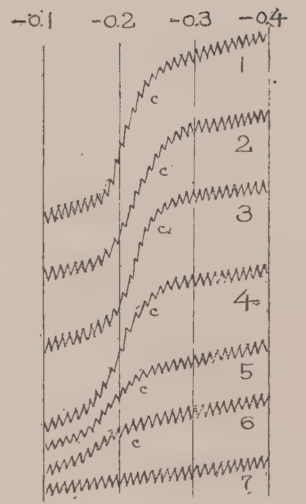


0.01 M アスコルビン酸 0.1cc に 1.0×10^{-5}M $CuSO_4$ 0.1cc を加え更に 0.1 M 枸櫞酸 3.0cc を加え pH 7.0 の燐酸緩衝液にて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4}M

酸化電位 1. +0.160 volt（1 規定甘汞電極を基準）
2. +0.165 〃（〃）
3. +0.162 〃（〃）
4. +0.167 〃（〃）
5. +0.170 〃（〃）

第 81 図

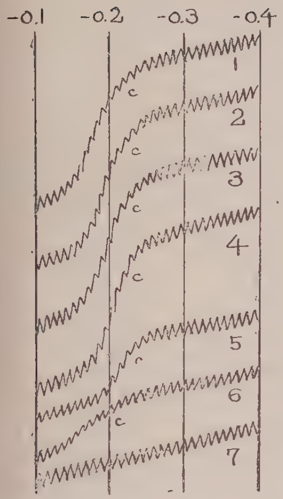


0.01 M アスコルビン酸 0.1cc に 1.0×10^{-3}M $CuSO_4$ 0.1cc を加え更に 0.1 M 枸櫞酸 4.0cc を加え pH 7.0 の燐酸緩衝液にて 5cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4}M

酸化電位 1. +0.170 volt（1 規定甘汞電極を基準）
2. +0.165 〃（〃）
3. +0.167 〃（〃）
4. +0.172 〃（〃）
5. +0.175 〃（〃）

第　図



01 M アスコルビン酸 0.1 cc に
1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え
更に 0.1 M 枸櫞酸 4.8 ccを加えた
るもの
アスコルビン酸の濃度は
2.0×10^{-4} M
酸化電位 1. +0.190 volt （1 規定
甘汞電極を基準）
2. +0.190 〃 （ 〃 ）
3. +0.187 〃 （ 〃 ）
4. +0.182 〃 （ 〃 ）
5. +0.185 〃 （ 〃 ）

3. 硫酸銅を添加せざる 1 の場合と、添加せる 2 の場合との比較

硫酸銅を加えざるもののアスコルビン酸溶液添加直後のポーラログラムの酸化波の高さを 100% として、硫酸銅を加えたるものとアスコルビン酸の残存率を比較して見ると、第 11 表及び第 83 図に示す如く、硫酸銅を加えざるものは 6 時間後に於て比較するに、枸櫞酸の添加 1 cc のものはその残存率は 50%、2 cc 及び 3 cc 加えたものは 87%、4 cc 以上加えたものは 90% 以上である。24 時間後に於ても枸櫞酸の添加 2 cc 以上のものは 50% 前後の残存率を示し、硫酸銅を加えたものは、直後に於て何れも多少残存率は減少しているが、枸櫞酸の添加量 4 cc 以上のものは硫酸銅を加えざるものと比較して、6 時間後に於て 2～4%、24 時間後に於ても 10% 前後減少しているに過ぎない。即ち枸櫞酸はその pH が大体 5.0 以上となれば著しくアスコルビン酸の安定性に対して効果的であり、銅の接触的酸化に対しても同様に有効なる抑止作用を有している。

第 11 表

枸櫞酸に $CuSO_4$ 添加の有無によるアスコルビン酸の残存率の比較

		$CuSO_4$ を加えざるもの					$CuSO_4$ を加えたるもの				
枸櫞酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後	直後	2時間後	1時間後	6時間後	24時間後
cc		%	%	%	%	%	%	%	%	%	%
0.1	6.4	100	54	21	—	—	96	16	—	—	—
0.5	6.0	100	80	47	40	—	96	23	13	—	—
1.0	5.5	100	83	57	50	—	96	47	33	23	—
2.0	5.0	100	97	94	87	42	96	87	78	74	19
3.0	3.2	100	97	94	87	48	96	90	87	87	29
4.0	2.4	100	97	94	90	56	96	90	88	88	44
※ 4.9	2.0	100	97	94	94	56	96	94	90	90	47

※ $CuSO_4$ を加えたるものは 4.8cc

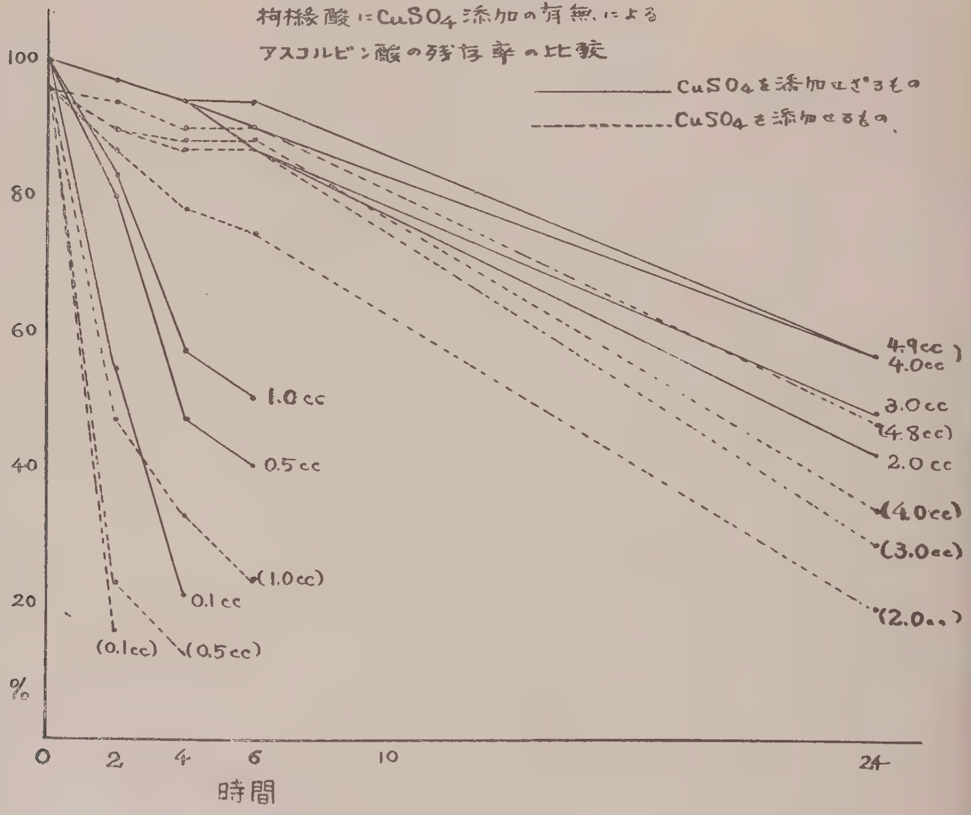
要　旨

1.　2.0×10^{-4} M のアスコルビン酸の濃度に於て、枸櫞酸の添加量大なる程即ち酸性が大とる程アスコルビン酸の自動酸化に対して有効である。

2.　硫酸銅を加えた場合も同様で、枸櫞酸の添加量大なる程銅の接触酸化に対して抑止作用有し有効なる結果が得られた。

3.　第 4 章の結果と比較して見ると大体同様の傾向を示すが、同一 pH に於ては枸櫞酸のが効果的である。

第 83 図



第　6　章

ビタミン C の安定性に対する枸櫞酸加里（中性塩）の効果

ビタミン C の安定性に対し有機酸の塩類に就ての報告は未だない。著者は第 1 章に於て、

タミン C をポーラログラフ的に定量する場合 pH 7.0 の燐酸緩衝液のみでは一定の高さの酸化波を有するポーラログラムは得られなかつた。それで枸櫞酸加里液溶液を少量加えた場合に、ビタミン C 定量の標準となす事の出来る一定の高さの酸化波を有するポーラログラムが得られた。それで枸櫞酸加里はビタミン C の自酸化に対し抑止作用を有することを知り、ビタミン C の安定性に対する枸櫞酸加里の効果及び之に硫酸銅を加えた場合の接触的酸化に対する抑止作用に就て前章同様の実験を試みた次第である。

實驗の部

実験に関するすべての條件は前章と同様である。尚本実験に用いた枸櫞酸加里は中性塩（Tri-Potassium Citrate）である

1. ビタミン C の安定性に対する枸櫞酸加里の効果

各々に 0.01 M のアスコルビン酸 0.01 cc を加え之に 0.1 M の枸櫞酸加里を夫々 0.1、0.5、1.0、2.0、3.0、4.0、4.9 cc を加え、更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し枸櫞酸加里の添加 4.9 cc の場合は燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つた。

その結果第 12 表にアスコルビン酸の酸化波の高さ及び酸化電位を、第 84 図にその酸化波の高さの変化を示し、第 85 図〜第 91 図にそのポーラログラムを示した。（図の 1、2、3、4、5、6 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後、に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。以下同様）

第 12 表

枸櫞酸加里添加によるアスコルビン酸の酸化波の高さ及び酸化電位

枸櫞酸加里添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
cc		mm	mm	mm	mm	mm
0.1	7.0	24	12	8	2	—
0.5	6.8	26	16	9	5	—
1.0	6.6	28	17	14	12	—
2.0	6.4	29	23	20	19	3
3.0	6.2	30	24	23	20	6
4.0	6.2	30	25	24	22	8
4.9	6.0	30	25	24	22	10

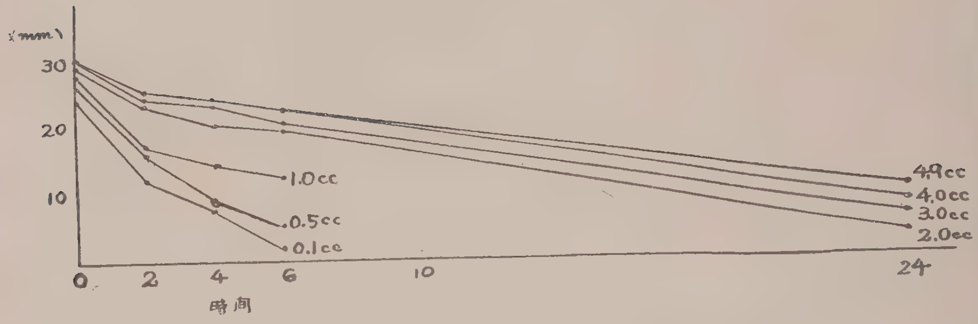
酸化電位

（1規定甘汞電極を基準）

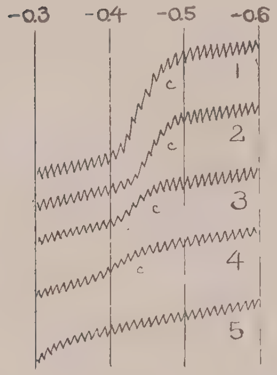
cc		volt	volt	volt	volt	volt
0.1	7.0	−0.042	−0.043	−0.040	−0.046	—
0.5	6.8	−0.041	−0.038	−0.040	−0.039	—
1.0	6.6	−0.040	−0.041	−0.039	−0.042	—
2.0	6.4	−0.032	−0.031	−0.034	−0.032	−0.032
3.0	6.2	−0.032	−0.036	−0.034	−0.032	−0.032
4.0	6.2	−0.035	−0.031	−0.029	−0.032	−0.032
4.9	6.0	−0.035	−0.036	−0.034	−0.032	−0.027

第 84 図

枸櫞酸加量添加によるアスコルビン酸の
酸化波の高さの變化



第 85 図

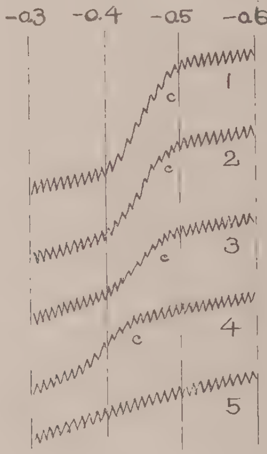


0.01 M アスコルビン酸 0.1 cc に 0.1 M K-citrate 0.1 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. −0 042 volt (1 規定甘汞電極を基準)
2. −0.043 〃 (〃)
3. −0.010 〃 (〃)
4. −0.016

第 86 図

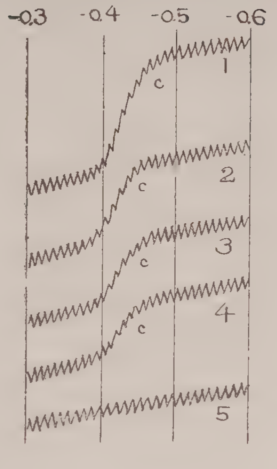


0.01 M アスコルビン酸 0.1 cc に 0.1 M K-citrate 0.5 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc なせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

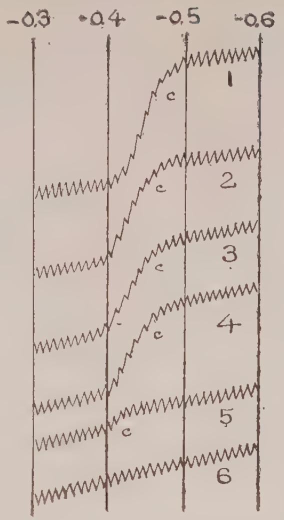
酸化電位 1. −.0 041 volt1 (1 規定甘汞電
を基準)
2. −0 038 〃 (〃)
3. −0 040 〃 (〃)
4. −0.039 〃 (〃)

第 87 図



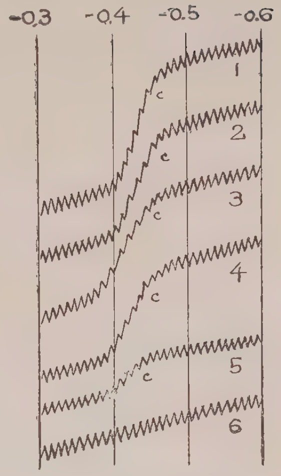
0.01 M アスコルビン酸 0.1 cc に 0.1 M K-citrte 1.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は
2.0×10^{-4} M
酸化電位 1. −0.010 volt（1 規定甘汞電極を基準）
2. −0 041 〃（〃）
3. −0.030 〃（〃）
4. −0 012 〃（〃）

第 88 図



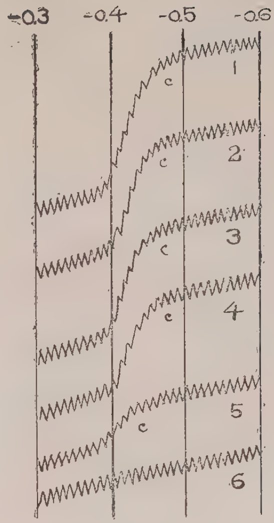
0.01 M アスコルビン酸 0.1 cc に 0.1 M K-citrate 2.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は
2.0×10^{-4} M
酸化電位 1. −0.035 volt（1 規定甘汞電極を基準）
2. −0.031 〃（〃）
3. −0.024 〃（〃）
4. −0.032 〃（〃）
5. −0.032 〃（〃）

第 89 図



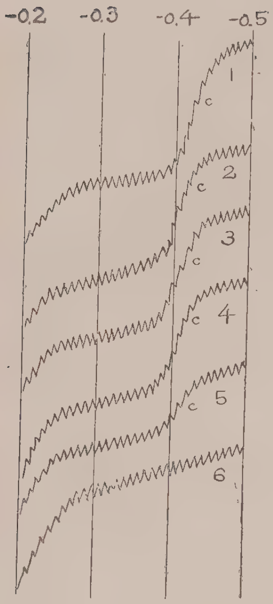
0.01 M アスコルビン酸 0.1 cc に 0.1 M K-citrate 3.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は
2.0×10^{-4} M
酸化電位 1. −0.032 volt（1 規定甘汞電極を基準）
2. −0.036 〃（〃）
3. −0.034 〃（〃）
4. −0.032 〃（〃）
5. −0.032 〃（〃）

第 90 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M K-citrate 4.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は
2.0×10^{-4} M
酸化電位 1. −0.035 volt（1 規定甘汞電極を基準）
2. −0.031 〃（〃）
3. −0.029 〃（〃）
4. −0.032 〃（〃）
5. −0.032 〃（〃）

第 91 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M K-citrate 4.9 cc を加えたるものアスコルビン酸の濃度は 2.0×10^{-4} M

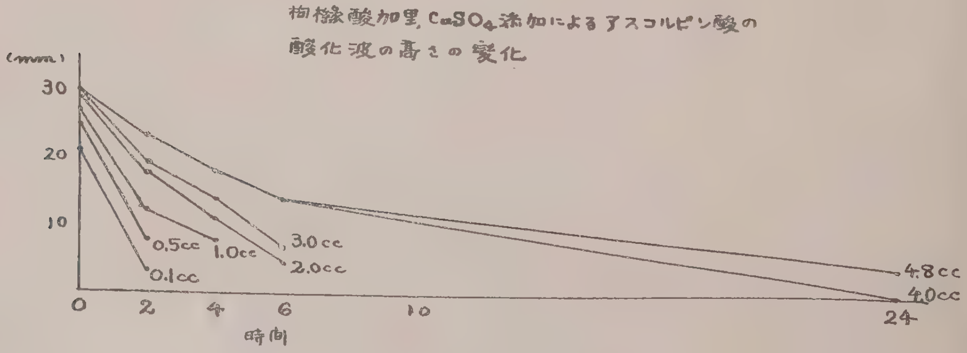
酸化電位 1. −0 035 volt（1 規定甘汞電極を基準）
2. − 0.036 〃 (〃)
3. −0.034 〃 (〃)
4. −0.032 〃 (〃)
5. −0.027 〃 (〃)

2. 前記 1 の場合に硫酸銅を添加せる時の影響

前章2の場合と同様に銅イオンの接触的酸化抑止作用を見るために前記枸櫞酸加里添加の各液に夫々 1.0×10^{-4} M の硫酸銅 0.1 cc を加え液の総量を燐酸緩衝液にて 5 c となし（但し前記枸櫞酸加里 4.9 cc 添加のものは此の場合枸櫞酸加里の添加は 4.8 cc となし燐酸緩衝液は加えたかつた）前記同様時間の経過と共にポーラログラムを撮つた。

その結果第 13 表にアスコルビン酸の酸化波の高さ及び酸化電位を、第 92 図にその酸化波の高さの変化を示し、第 93 図～第 99 図にそのポーラログラムを示した。

第 92 図



第 13 表

枸櫞酸加里に $CuSO_4$ を添加せる場合のアスコルビン酸の酸化波の高さ及び酸化電位

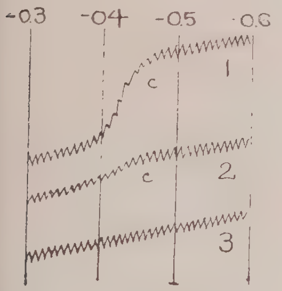
枸櫞酸加里添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
cc		mm	mm	mm	mm	mm
0.1	7.0	21	3	—	—	—
0.5	6.8	25	8	—	—	—
1.0	6.6	27	12	8	—	—
2.0	6.4	29	18	11	5	—
3.0	6.2	30	19	14	7	—
4.0	6.2	30	23	18	14	—
4.8	6.0	30	23	18	14	4

酸　化　電　位

（1規定甘汞電極を基準）

枸櫞酸加里添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
cc		volt	volt	volt	volt	volt
0.1	7.0	−0.031	−0.032	—	—	—
0.5	6.8	−0.036	−0.037	—	—	—
1.0	6.6	−0.036	−0.032	−0.035	—	—
2.0	6.4	−0.032	−0.037	−0.031	−0.032	—
3.0	6.2	−0.032	−0.032	−0.029	−0.032	—
4.0	6.2	−0.032	−0.027	−0.029	−0.032	—
4.8	6.0	−0.027	−0.032	−0.029	−0.032	−0.028

第 93 図



0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M$CuSO_4$ を 0.1 cc 加え更に 0.1 M K-citrate 0.1 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの

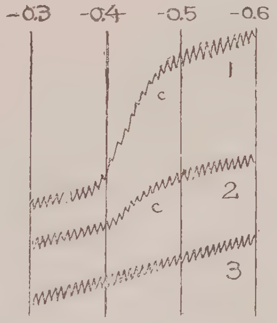
アスコルビン酸の濃度は

2.0×10^{-1} M

酸化電位 1. −0.031 volt（1規定甘汞電極を基準）

2. −0.032 〃（〃）

第 94 図



0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0.0.1 M K-citrate 0.5 cc を加え pH 7.0 の燐酸緩衝液にて5ccとなせるもの

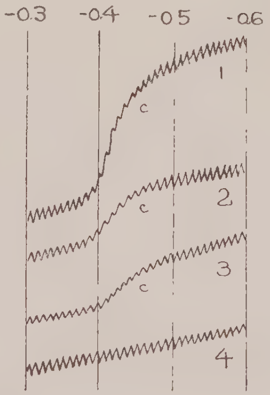
アスコルビン酸の濃度は

2.0×10^{-4} M

酸化電位 1. −0.037 volt（1規定甘汞電極を基準）

2. −0.037 〃（〃）

第 95 図



0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0.1 M K-citrate 1.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度に

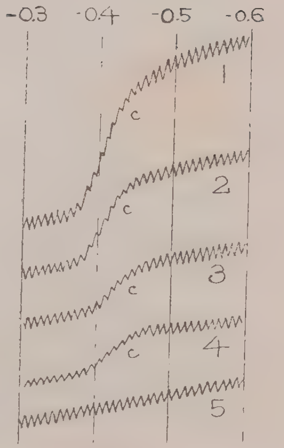
2.0×10^{-4} M

酸化電位 1. −0.036 volt（1定規甘汞電極を基準）

2. −0.032 〃（〃）

3. −0.035 〃（〃）

第 96 図

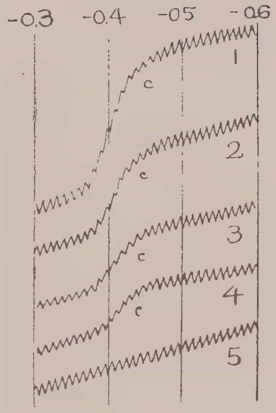


0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0.1 M K-citrate 2.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は
2.0×10^{-4} M

酸化電位 1. −0.032 volt (1 規定甘汞電極を基準)
2. −0.037 〃 (〃)
3. −0.031 〃 (〃)
4. −0.032 〃 (〃)

第 97 図

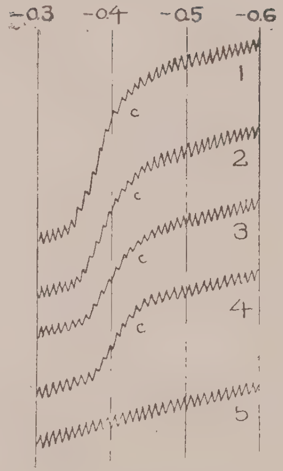


0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-5} M $CuSO_4$ 0.1 cc を加え更に 0.1 M K-citrate 3.0 cc を加え pH 7.0 の燐酸緩衝液を加え 5 cc となせるもの

アスコルビン酸の濃度は
2.0×10^{-4} M

酸化電位 1. −0.032 volt (1 規定甘汞電極を基準)
2. −0.032 〃 (〃)
3. −0.029 〃 (〃)
4. −0.032 〃 (〃)

第 98 図

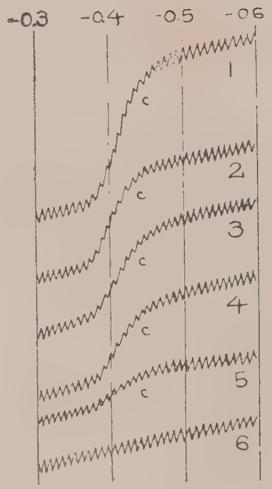


0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0.1 M K-citrate 4.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの

アスコルビン酸の濃度は
2.0×10^{-4} M

酸化電位 1. −0.032 volt (1 規定甘汞電極を基準)
2. −0.027 〃 (〃)
3. −0.029 〃 (〃)
4. −0.032 〃 (〃)

第 99 図



0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0.1 M K-citrate 4.8 cc を加えたるもの

アスコルビン酸の濃度は
2.0×10^{-4} M

酸化電位 1. −0.027 volt (1 規定甘汞電極を基準)
2. −0.032 〃 (〃)
3. −0.029 〃 (〃)
4. −0.032 〃 (〃)
5. −0.028 〃 (〃)

3. 硫酸銅を添加せざる 1 の場合と硫酸銅を添加せる 2 の場合との比較

硫酸銅を加えざるもののアスコルビン酸添加直後のポーラログラムの酸化波の高さを 100 % となし、硫酸銅を加えたるものとアスコルビン酸の残存率を比較して見ると、第 14 表及び第 100 図に示す如く何れも枸櫞酸加里の添加量の増大と共に効果的である。即ち 6 時間後に於て枸櫞酸加里 1 cc 以上添加せるものは約 50 % 以上を残存し、硫酸銅を添加せるものに於ても、4 cc 以上を添加せるものは約 50 % を残存している。

尚第 4 章、第 5 章に於ける結果と同一 pH に於てアスコルビン酸の残存率を比較し、pH 6.0 に於ける結果を比較して見ると第 15 表に示す如く枸櫞酸加里を添加せるものは他のものに比較して効果的である。

これに依つて見るにアスコルビン酸は必ずしも酸度のみによつて安定性は左右されるものではなく、有機酸の塩類もアスコルビン酸の自酸化に対して抑止作用を有するものである。

第 14 表

枸櫞酸加里に$CuSO_4$の添加の有無によるアスコルビン酸の残存率比較

枸櫞酸加里添加量	pH	$CuSO_4$を加えざるもの					$CuSO_4$を加えたるもの				
		直後	2時間後	4時間後	6時間後	24時間後	直後	2時間後	4時間後	6時間後	24時間後
cc		%	%	%	%	%	%	%	%	%	%
0.1	7.0	100	52	30	8	—	88	12	—	—	—
0.5	6.8	100	60	36	11	—	96	31	—	—	—
1.0	6.6	100	61	52	48	—	96	43	28	—	—
2.0	6.4	100	78	67	65	9	100	62	38	17	—
3.0	6.2	100	79	77	66	21	100	63	47	23	—
4.0	2.2	100	82	79	74	28	100	80	60	47	—
※ 4·9	6.0	100	82	79	74	33	100	80	60	47	13

※ $CuSO_4$を加えたるものは 4.8 cc

第 15 表

pH 6.0 に於けるアスコルビン酸残存率の比較

溶液 pH＝6.0	$CuSO_4$を加えざるもの					$CuSO_4$を加えたるもの				
	直後	2時間後	4時間後	6時間後	24時間後	直後	2時間後	4時間後	6時間後	24時間後
	%	%	%	%	%	%	%	%	%	%
枸櫞酸緩衝液	100	72	55	38	10	93	48	25	14	—
枸櫞酸加里	100	82	79	74	33	100	80	60	47	13
枸櫞酸	100	80	47	40	—	96	23	13	—	—

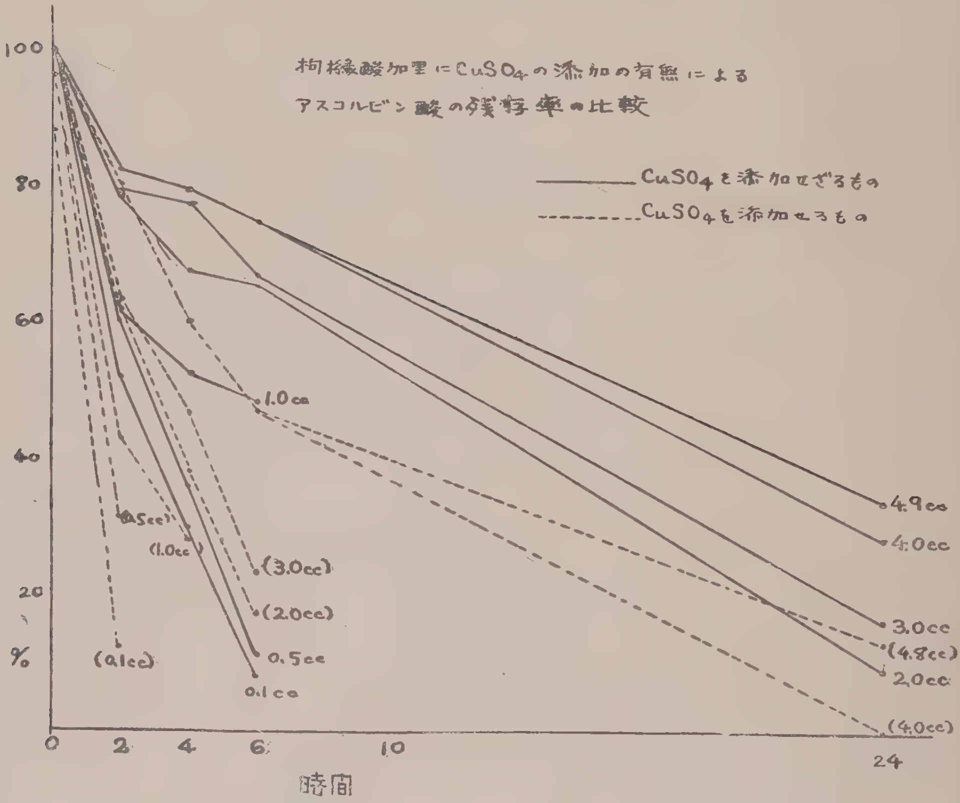
要旨

1. 枸櫞酸加里はアスコルビン酸の自酸化に対して或程度有効である。

2. 枸櫞酸加里は銅の接触的酸化に対しても或程度の抑止作用を有す。

3. アスコルビン酸は酸度のみによつて安定性は左右されるものではない。

第100図



第7章

ビタミンの C 安定性に対する枸櫞酸1加里の効果

ビタミンCの安定性に対する枸櫞酸1加里の効果に就てポーラログラフ的に次の実験を
みた。

實驗の部

実験に関するすべての條件は前章と同様である。

各々に0.01Mのアスコルビン酸溶液0.1ccを加え之に0.1Mの枸櫞酸1加里を夫々0.5、1.0、2.0、3.0、4.0、4.9ccを加え更にpH 7.0の燐酸緩衝液を加えて5ccとなし（但し枸櫞

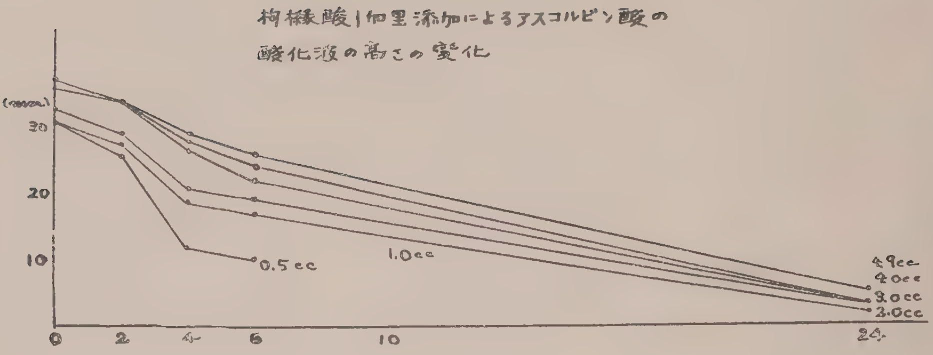
酸 1 加里 4.9 cc 添加の場合は燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つた。その結果は第 16 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 101 図にその酸化波の高さの変化を示し、第 102 図～第 107 図にそのポーラログラムを示した（図の1、2、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 16 表

枸櫞酸 1 加里添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

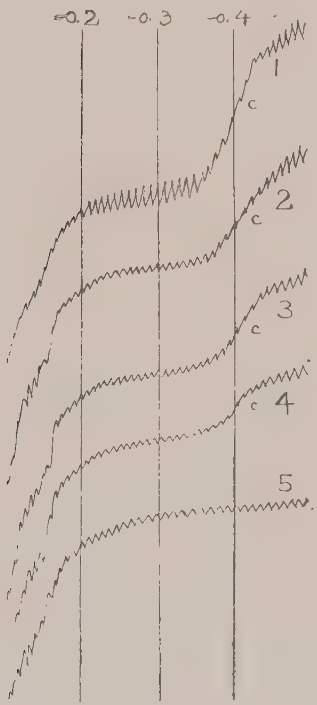
枸櫞酸 1 加里添加量	pH	直後	2 時間後	4 時間後	6 時間後	24時間後
			酸化波の高さ			
cc		mm	mm	mm	mm	mm
0.5	5.6	31	26	12	10	—
1.0	5.0	31	28	19	17	2
2.0	4.7	33	29	21	19	3
3.0	4.5	36	34	27	22	3
4.0	4.4	37	34	28	24	3
4.9	4.2	37	34	29	26	5
			酸化電位 （1 規定甘汞電極を基準）			
cc		volt	volt	volt	volt	volt
0.5	5.6	+0.043	+0.048	+0.041	+0.043	—
1.0	5.0	+0.053	+0.053	+0.051	+0.048	+0.051
2.0	4.7	+0.073	+0.073	+0.071	+0.073	+0.076
3.0	4.5	+0.079	+0.079	+0.076	+0.079	+0.076
4.0	4.4	+0.089	+0.089	+0.086	+0.089	+0.085
4.9	4.2	+0.094	+00.89	+0.991	+0.095	+0.095
			残存率			
		%	%	%	%	%
0.5	5.6	100	84	39	32	—
1.0	5.0	100	90	61	55	6
2.0	4.7	100	88	64	58	9
3.0	4.5	100	94	75	61	8
4.0	4.4	100	92	76	65	8
4.9	4.2	100	92	78	70	14

第 101 図



枸櫞酸1加里添加によるアスコルビン酸の酸化波の高さの変化

第 102 図

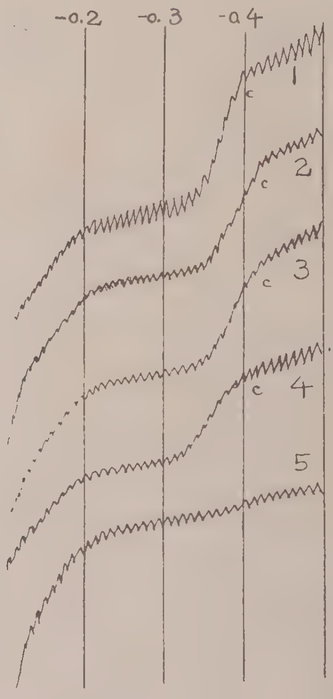


0.01 M アスコルビン酸 0.1 cc に 0.1 M 1-K-citrate 0.5 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10⁻⁴ M

酸化電位 1. +0.043 volt（1 規定甘汞電極を基準）
2. +0.048 〃 （ 〃 ）
3. +0.041 〃 （ 〃 ）
4. +0.043 〃 （ 〃 ）

第 103 図

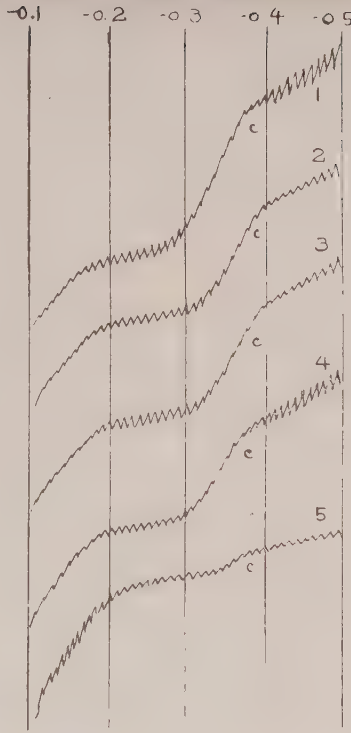


0.01 M アスコルビン酸 0.1 cc に 0.1 M 1-K-citrate 1.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10⁻⁴ M

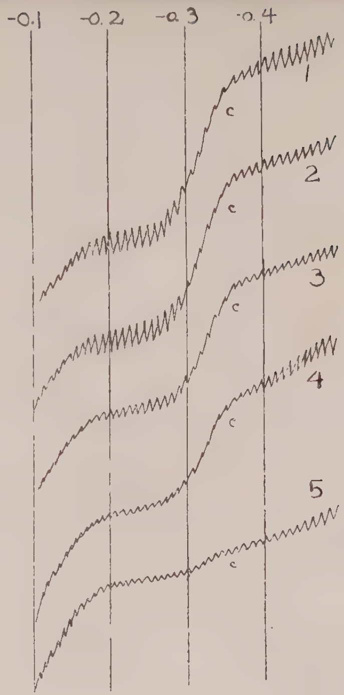
酸化電位 1. +0.053 volt（1 規定甘汞電極を基準）
2. +0.053 〃 （ 〃 ）
3. +0.051 〃 （ 〃 ）
4. +0.048 〃 （ 〃 ）
5. +0.051 〃 （ 〃 ）

第 104 図



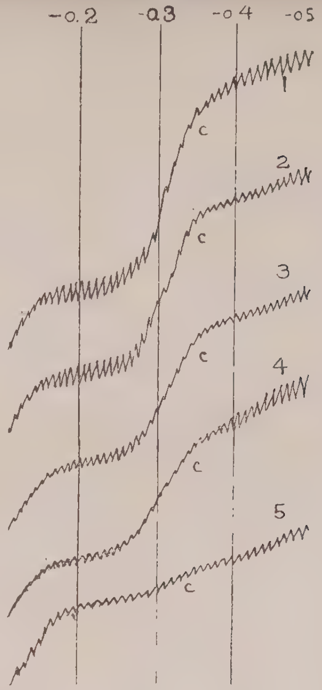
0.01 M アスコルビン酸 0.1 cc に 0.1 M
I-K-citrate 2.0 cc を加え pH 7.0 の燐酸
緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.053 volt （1規定甘汞電極を基準）
2. +0.053 〃 （ 〃 ）
3. +0.051 〃 （ 〃 ）
4. +0.048 〃 （ 〃 ）
5. +0.051 〃 （ 〃 ）

第 105 図



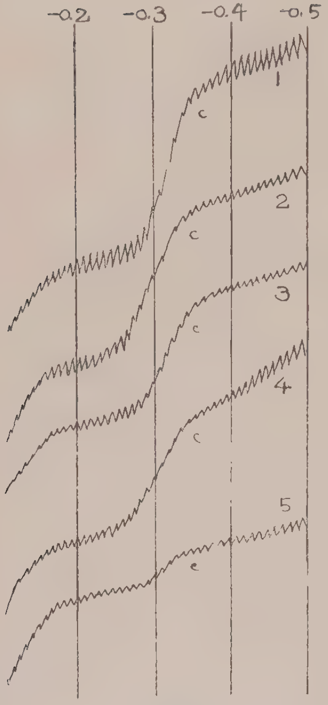
0.01 M アスコルビン酸 0.1 cc に 0.1 M
I-K-citrate 3.0 cc を加え pH 7.0 の燐酸
緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.079 volt （1規定甘汞電極を基準）
2. +0.079 〃 （ 〃 ）
3. +0.076 〃 （ 〃 ）
4. +0.079 〃 （ 〃 ）
5. +0.076 〃 （ 〃 ）

第 106 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M
I-K-citrate 4.0 cc を加え pH 7.0 の燐酸
緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.089 volt （1規定甘汞電極を基準）
2. +0.089 〃 （ 〃 ）
3. +0.080 〃 （ 〃 ）
4. +0.089 〃 （ 〃 ）
5. +0.085 〃 （ 〃 ）

第 107 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M I-K-citrate 4.9 cc を加えたるもの
アスコルビン酸の濃度は
2.0×10⁻⁴ M
酸化電位 1. +0.094 volt (1 規定甘汞電極を基準)
2. +0 089 〃 (〃)
3. +0.091 〃 (〃)
4. +0.095 〃 (〃)
5. +0.090 〃 (〃)

第 16 表及び第 101 図〜第 107 図に示す如く、6 時間後に於て枸櫞酸 1 加里 2 cc 以上添加せるものは約 10 % のアコルビン酸を残存し或程度の安定性がある。枸櫞酸 1 加里中性塩なる枸櫞酸加里と比較して酸度は高いが安定性に対してかは中性に近い枸櫞酸加里の方が効果的である。

要　　旨

1. 枸櫞酸 1 加里はアスコルビン酸の安定性に対して或程度の効果がある。

2. 枸櫞酸 1 加里は枸櫞酸加里（中性塩）より酸度は高いがアスコルビン酸の安定性に対しては劣つている。

第　8　章

ビタミン C の安定性に対する枸櫞酸 2 加里の効果

ビタミン C の安定性に対する枸櫞酸 2 加里の効果に関しポーラログラフ的に次の実験を試みた。

實驗の部

実験に関するすべての條件は前章と同様である。

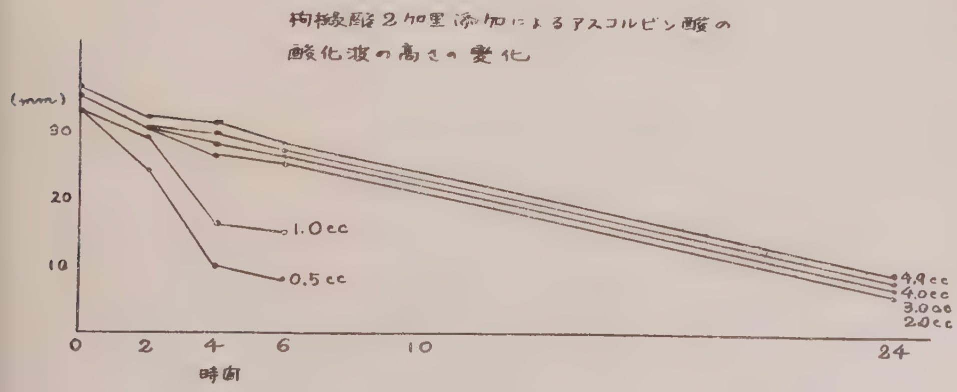
各々に 0.01 M のアスコルビン酸溶液 0.1 cc を加え、之に 0.1 M の枸櫞酸 2 加里を夫々 0.5、1.0、2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し枸櫞酸 2 加里 4.9 cc 添加の場合は燐酸緩衝液は加えなかつた）前章同様時間の経過と共にポーラログラムを撮つた。その結果は第 17 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 108 図にその酸化波の高さの変化を示し、第 109 図〜第 114 図にそのポーラログラムを示した。（図の 1、2、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} である）

第 17 表

枸櫞酸2加里添加によるアスコルビン酸の酸化酸の高さ、酸化電位及び残存率

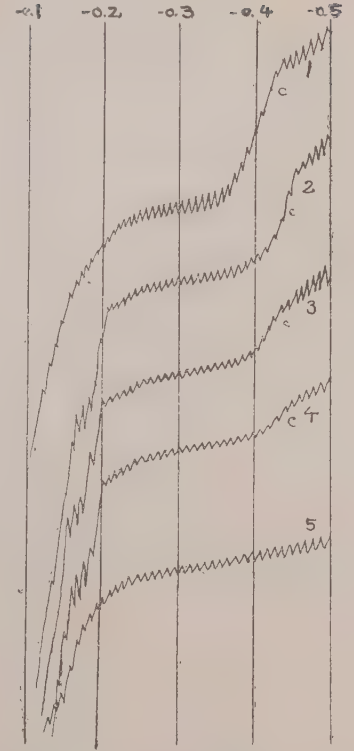
枸櫞酸2加里添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
			酸化波の高さ			
cc		mm	mm	mm	mm	mm
0.5	6.8	33	24	10	8	—
1.0	6.5	33	29	16	15	—
2.0	6.3	35	30	26	25	6
3.0	5.8	35	30	28	26	7
4.0	5.7	35	30	29	27	8
4.9	5.2	36	32	31	28	9
			酸化電位 （1規定甘汞電極を基準）			
cc		volt	volt	volt	volt	volt
0.5	6.8	+0.036	+0.037	+0.034	+0.034	—
1.0	6.5	+0.041	+0.037	+0.039	+0.041	—
2.0	6.3	+0.066	+0.032	+0.064	+0.061	+0.061
3.0	5.8	+0.075	+0.075	+0.077	+0.076	+0.071
4.0	5.7	+0.087	+0.085	+0.084	+0.089	+0.084
4.9	5.2	+0.092	+0.090	+0.097	+0.091	+0.093
			残存率			
cc		%	%	%	%	%
0.5	8.6	100	73	30	24	—
1.0	6.5	100	88	50	45	—
2.0	6.3	100	86	74	71	17
3.0	5.8	100	86	80	74	20
4.0	5.7	100	86	83	77	23
4.9	5.2	100	89	86	76	25

第 108 図



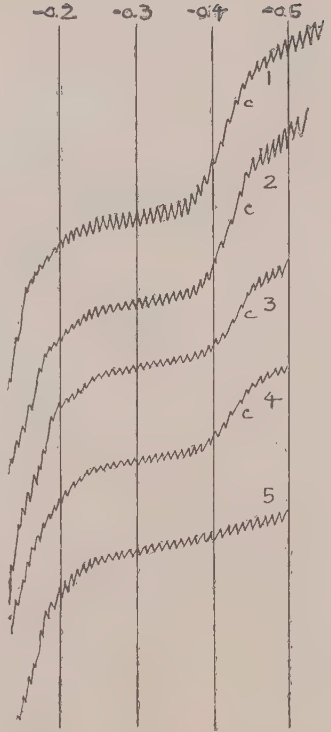
枸櫞酸2加里添加によるアスコルビン酸の
酸化波の高さの変化

第 109 図



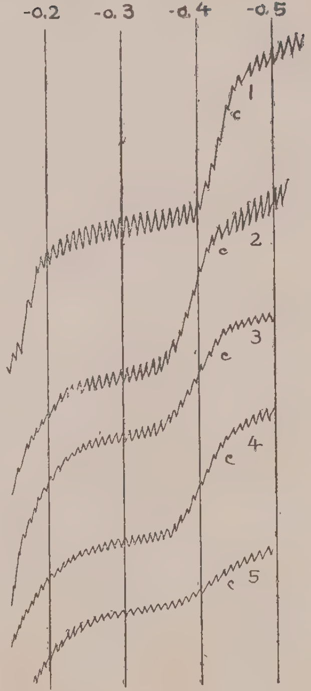
0.01 M アスコルビン酸 0.1 cc に
0.1 M 2-K-citrate 0.5 cc を加え
pH 7.0 の燐酸緩衝液にて 5 cc と
なせるもの
アスコルビン酸の濃度は
2.0×10^{-4} M
酸化電位 1. +0.036 volt（1 規定甘汞電極を基準）
2. +0.037 〃 （〃）
3. +0.034 〃 （〃）
4. +0.034 〃 （〃）

第 110 図



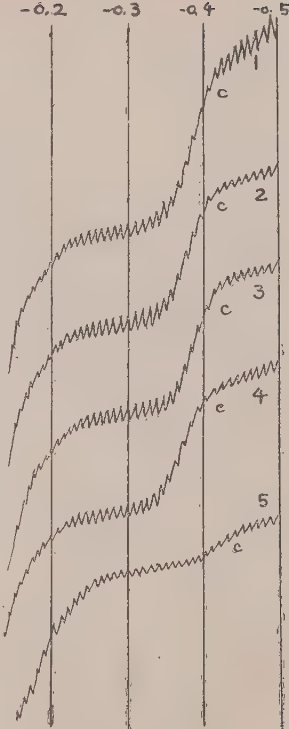
0.01 M アスコルビン酸 0.1 cc に
0.1 M 2-K-citrate 1.0 cc を加え
pH 7.0 の燐酸緩衝液にて 5 cc と
なせるもの
アスコルビン酸の濃度は
2.0×10^{-4} M
酸化電位 1. +0.011 volt（1 規定甘汞電極を基準）
2. +0.037 〃 （〃）
3. +0.039 〃 （〃）
4. +0.041 〃 （〃）

第 111 図



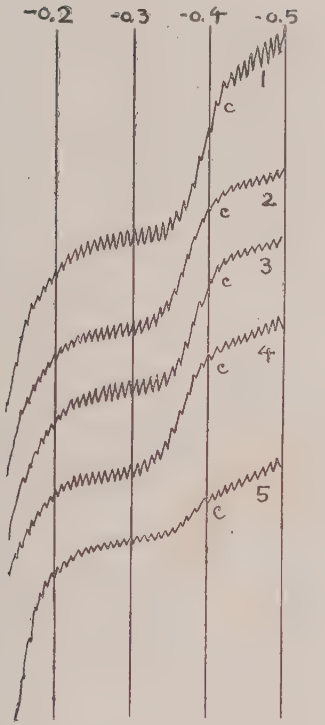
0.01 M アスコルビン酸 0.1 cc に
0.1 M 2-K-citrate 2.0 cc を加え
pH 7.0 の燐酸緩衝液にて 5 cc と
なせるもの
アスコルビン酸の濃度は
2.0×10M^{-4} M
酸化電位 1. +0.036 volt（1 規定甘汞電極を基準）
2. +0.062 〃 （〃）
3. +0.064 〃 （〃）
4. +0.066 〃 （〃）
5. +0.031 〃 （〃）

第 112 図



0.01 M アスコルビン酸 0.1 cc に
0.1 M 2-K-citrate 3.0 cc を加え
pH 7.0 の燐酸緩衝液を加え 5 cc
となせるもの
アスコルビン酸の濃度は
2.0×10^{-4} M
酸化電位 1. +0.075 volt（1 規定甘汞電極を基準）
2. +0.075 〃 （〃）
3. +0.077 〃 （〃）
4. +0.076 〃 （〃）
5. +0.071 〃 （〃）

第 113 図

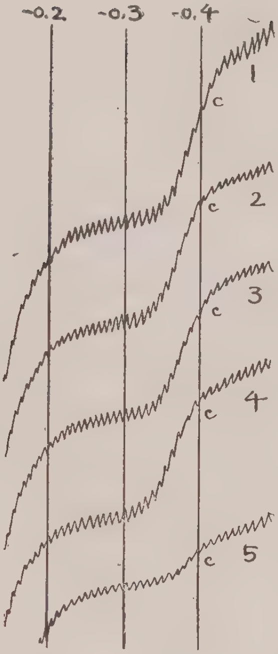


0.01 M アスコルビン酸 0.1 cc に 0.1 M 2-K-citrate 4.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. +0.087 volt （1規定甘汞電極を基準）
2. +0.085 〃 （ 〃 ）
3. +0.084 〃 （ 〃 ）
4. +0.089 〃 （ 〃 ）
5. +0.084 〃 （ 〃 ）

第 114 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M 2-K-citrate 4.9 cc を加えたるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. +0.092 volt （1規定甘汞電極を基準）
2. +0.090 〃 （ 〃 ）
3. +0.097 〃 （ 〃 ）
4. +0.091 〃 （ 〃 ）
5. +0.093 〃 （ 〃 ）

第 17 表及び第 108 図～第 114 図に示す如く、枸櫞酸 2 加里 2 cc 以上添加せるものは 24 時間後に於ても約 20 % のアスコルビン酸を残存し、枸櫞酸 1 加里よりも安定性に於て効果はあるが枸櫞酸加里より効果は少しく劣つている。即ち枸櫞酸の加里塩に於て酸度の低い塩の方がアスコルビン酸の安定性に対して効果がある。

要　　旨

1. 枸櫞酸 2 加里はアスコルビン酸の安定性に対して或程度の効果があり枸櫞酸 1 加里よりも効果的であるが枸櫞酸加里（中性塩）よりも劣る。

2. 枸櫞酸の加里塩に於て酸度の低い中性塩となるに従つて安定性は増加して來る。

第 9 章

ビタミン C の安定性に対する酒石酸の効果

ビタミン C の安定性に対する酒石酸の効果に関しては稲垣氏(84) の報告があり相当に有効
ることを示している。著者はこれをポーラログラフ的に前章と同様にアスコルビン酸の自酸化
対する安定性並びに銅イオンの接触的酸化に対する抑止作用を見るため次の実験を試みた次第
ある。

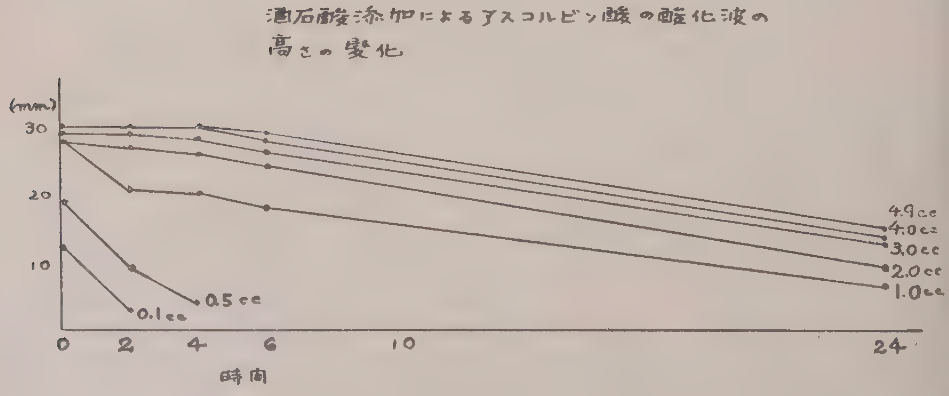
實験の部

実験に関するすべての條件は前章と同様である。

1. ビタミン C の安定性に対する酒石酸の効果

各々に 0.01 M のアスコルビン酸溶液 0.1 cc を加え、之に 0.1 M の酒石酸を夫々 0.1、0
1 0、2.0、3.0、4.0、4.9 cc を加え、更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし (但し
石酸 4.9 cc 添加の場合には燐酸緩衝液は加えなかつた) 前章と同様に時間の経過と共にポー
ログラムを撮つた。その結果は第 18 表にアスコルビン酸の酸化波の高さ及びその酸化電位
第 115 図にその酸化波の高さの変化を示し、第 116 図～第 122 図にそのポーラログラムを
した。(図の1、2、3、4、5、6 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6
後、24 時間後に於ける還元型アスコルビン酸の酸化波を示す、アスコルビン酸の濃度は
2.0×10^{-4} M である。以下同様

第 115 図

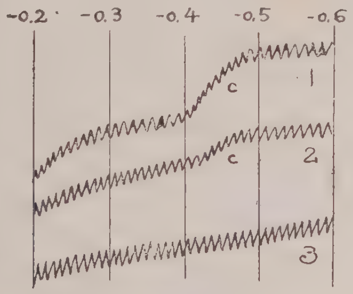


第 18 表

酒石酸添加によるアスコルビン酸の酸化波の高さ及び酸化電位

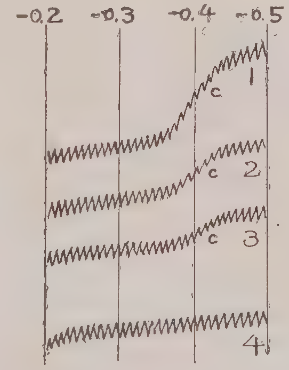
酒石酸添加量	pH	直　　後	2 時間後	4 時間後	6 時間後	24時間後
		酸化波の高さ				
cc		mm	mm	mm	mm	mm
0.1	6.4	12	3	—	—	—
0.5	5.4	19	9	4	—	—
1.0	3.8	28	21	20	18	6
2.0	2.4	28	27	26	24	9
3.0	2.2	29	29	28	26	13
4.0	1.8	30	30	30	28	14
4.9	1.4	30	30	30	29	15
		酸化電位 （1 規定甘汞電極を基準）				
cc		volt	volt	volt	volt	volt
0.1	6.4	−0.029	−0.029	—	—	—
0.5	5.4	−0.014	−0.014	−0.013	—	—
1.0	3.8	+0.123	+0.128	+0.128	+0.128	+0.123
2.0	2.4	+0.153	+0.151	+0.151	+0.151	+0.159
3.0	2.2	+0.178	+0.176	+0.174	+0.176	+0.179
4.0	1.8	+0.175	+0.178	+0.174	+0.176	+0.179
4.9	1.4	+0.200	+0.201	+0.199	+0.191	+0.209

第 116 図



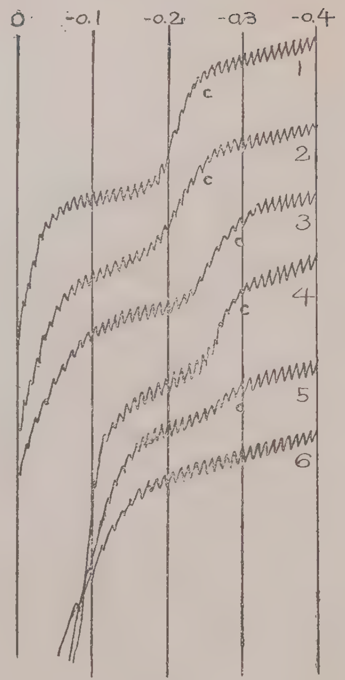
0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸 0.1 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.029 volt（1 規定甘汞電極を基準）
2. −0.029 〃 （〃）

第 117 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸 0.5 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.014 volt（1 規定甘汞電極を基準）
2. −0.014 〃 （〃）
3. −0.013 〃 （〃）

第 118 図



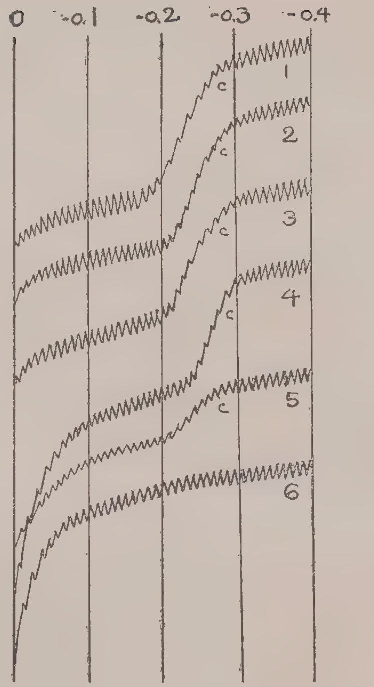
0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸 1.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10⁻⁴ M

酸化電位 1. +0.123 volt（1 規定甘汞電極を基準）

2. +0.128 〃 （ 〃 ）
3. +0.128 〃 （ 〃 ）
4. +0.128 〃 （ 〃 ）

第 119 図



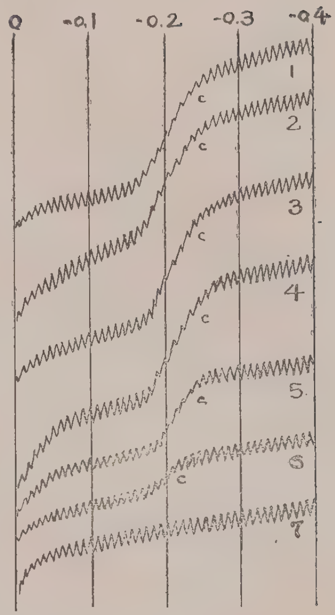
0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸 2.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの

アスコルビン酸の濃度に 2.0×10⁻⁴ M

酸化電位 1. +0.153 volt（1 規定甘汞電極を基準）

2. +0.151 〃 （ 〃 ）
3. +0.151 〃 （ 〃 ）
4. +0.151 〃 （ 〃 ）

第 120 図



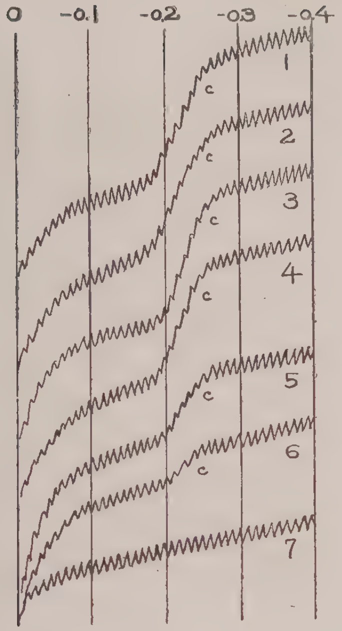
0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸 3.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10⁻⁴ M

酸化電位 1. +0.178 volt（1 規定甘汞電極を基準）

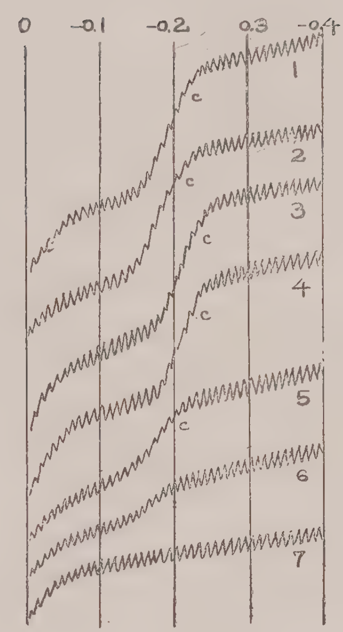
2. +0.176 〃 （ 〃 ）
3. +0.174 〃 （ 〃 ）
4. +0.176 〃 （ 〃 ）
5. +0.179 〃 （ 〃 ）

第 121 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M
酒石酸 4 0 cc を加え pH 7.0 の燐酸緩衝
液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.175 volt（1 規定甘汞電極を基準）
2. +0.178 〃（〃）
3. +0.174 〃（〃）
4. +0.176 〃（〃）
5. +0.179 〃（〃）

第 122 図

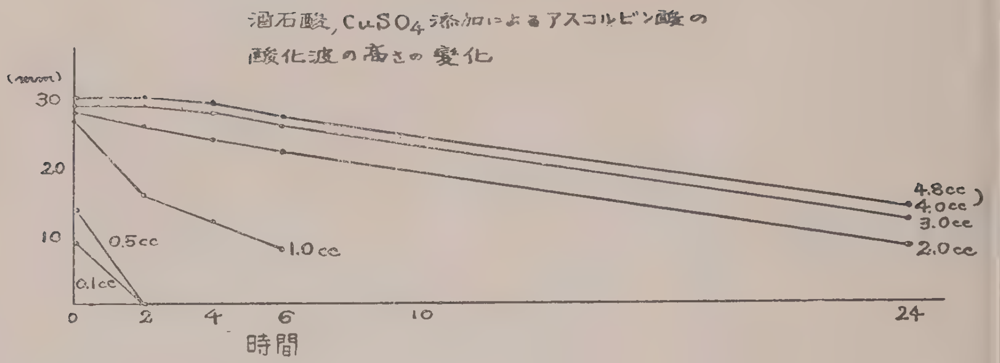


0 01 M アスコルビン酸 0.1 cc に 0.1 M
酒石酸を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.200 volt（1 規定甘汞電極を基準）
2. +0.201 〃（〃）
3. +0.199 〃（〃）
4. +0.191 〃（〃）
5. +0.209 〃（〃）

2. 前記 1 の場合に硫酸銅を添加せる時の影響

前記酒石酸添加の各液に夫々 1.0×10^{-3} M の硫酸銅 0.1 cc を加え液の総量を燐酸緩衝液にて cc となし（但し前記酒石酸 4.9 cc 添加のものは此の場合酒石酸の添加は 4.8 cc となし燐酸緩衝液は加えなかつた）前記同様ポーラログラムを撮つた。その結果は第 19 表にアスコルビン酸の酸化波の高さ及び酸化電位を、第 123 図にその酸化波の高さの変化を示し、第 124 図～第130 図にそのポーラログラムを示した。

第 123 図



第 19 表

酒石酸に $CuSO_4$ を添加せる場合のアスコルビン酸の酸化波の高さ及び酸化電位

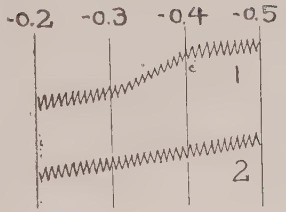
酒石酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
		酸化波の高さ				
cc		mm	mm	mm	mm	mm
0.1	6.4	9	—	—	—	—
0.5	5.4	14	—	—	—	—
1.0	3.8	27	16	12	8	—
2.0	3.4	28	26	24	22	8
3.0	2.2	29	29	28	26	12
4.0	1.8	30	30	29	27	14
4.9	1.4	30	30	29	27	14

酸化電位

（1規定甘汞電極を基準）

cc		volt	volt	volt	volt	volt
0.1	6.4	−0.030	—	—	—	—
0.5	5.4	−0.009	—	—	—	—
1.0	3.8	+0.102	+0.102	+0.108	+0.103	—
2.0	3.4	+0.152	+0.142	+0.148	+0.143	+0.148
3.0	2.2	+0.163	+0.154	+0.155	+0.158	+0.162
4.0	1.8	+0.173	+0.169	+0.175	+0.173	+0.172
4.8	1.4	+0.193	+0.195	+0.190	+0.193	+0.179

第 124 図

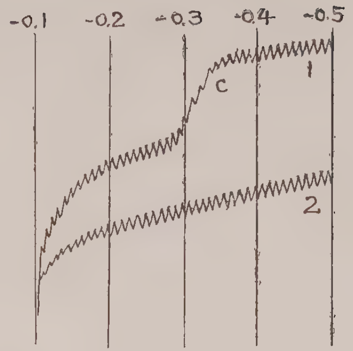


0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0.1 M の酒石酸 0.1 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. −0.030 volt（1 規定甘汞電極を基準）

第 125 図

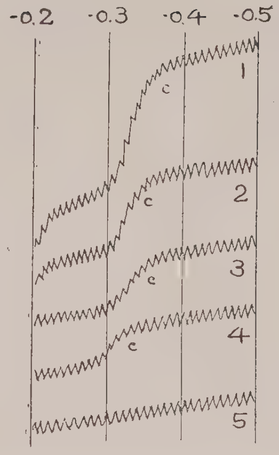


0·01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0 1 M 酒石酸 0.5 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. −0.009 volt（1 規定甘汞電極を基準）

第 126 図



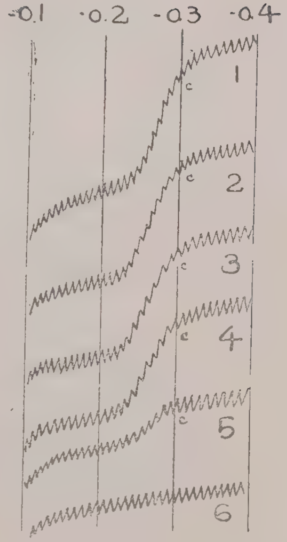
0 01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0.1 M 酒石酸 1.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. ＋0.102 volt（1 規定甘汞電極を基準）

2. ＋0.102 〃 （ 〃 ）
3. ＋0.108 〃 （ 〃 ）
4. ＋0.103 〃 （ 〃 ）

第 127 図



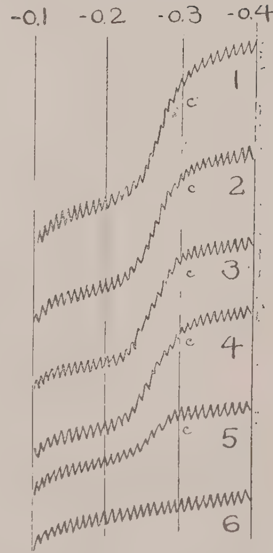
0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え更に 0.1 M 酒石酸 2.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. +0.152 volt (1 規定甘汞電極を基準)

2. +0.142 〃 (〃)
3. +0.148 〃 (〃)
4. +0.143 〃 (〃)
5. +0.148 〃 (〃)

第 128 図



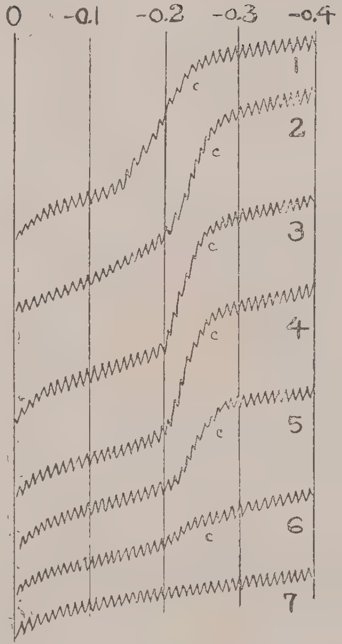
0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え 0.1 M 酒石酸 3.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. +0.163 volt (1 規定甘汞電極を基準)

2. +0.154 〃 (〃)
3. +0.155 〃 (〃)
4. +0.158 〃 (〃)
5. +0.162 〃 (〃)

第 129 図



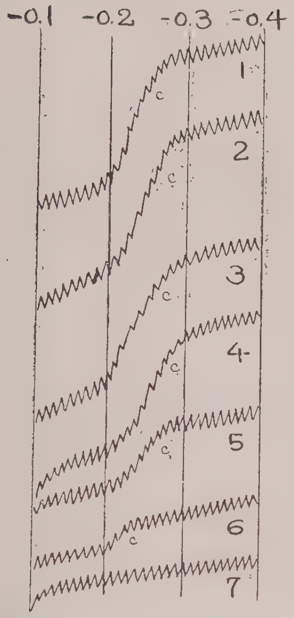
0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え 0.1 M の酒石酸 4.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. +0.173 volt (1 規定甘汞電極を基準)

2. +0.169 〃 (〃)
3. +0.175 〃 (〃)
4. +0.173 〃 (〃)
5. +0.172 〃 (〃)

第 130 図



0.01 M アスコルビン酸 0.1 cc に 1.0×10^{-3} M $CuSO_4$ 0.1 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アルコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.193 vclt（1 規定甘汞電極を基準）
2. +0.195 〃 （ 〃 ）
3. +0.190 〃 （ 〃 ）
4 +0.193 〃 （ 〃 ）
5. +0.197 〃 （ 〃 ）

3. 硫酸銅を添加せざる 1 の場合と、硫酸銅を添加せる 2 の場合との比較

硫酸銅を加えざるもののアスコルビン酸添加直後のポーラログラムの酸化波の高さを 100 % となし硫酸銅を加えたるものとその残存率を比較して見ると、第 20 表及び第 131 図に示す如く、アスコルビン酸の安定性に対しては何れも酒石酸の添加量の増大と共に効果的である。6 時間後に於ける酒石酸 2 cc 以上添加せるものは大体 90 % のアスコルビン酸を残存し、多少の差はあるが大体恒量となり、硫酸銅を加えた場合に於ても殆んど影響はなく銅イオンの接触的酸化に対しても相当の抑止作用を有するものである。

次に第 5 章の枸櫞酸添加の場合と同一の pH に於ける結果を pH 2.4 の場合に於て比較して見るに、第 21 表に示す如く 2〜6 時間後までは大差はないが 24 時間後に於て相当の差がある。

これによつて見るに同一 pH 2.4 に於ては枸櫞酸の方がアスコルビン酸の安定性に対して効果は持続性であつて酒石酸の場合よりも有効である。

第 20 表

酒石酸に $CnSO_4$ の添加の有無によるアスコルビン酸残存率比較

		$CuSO_4$ を加えざるもの					$CuSO_4$ を加えたるもの				
酒石酸添加量	pH	直後	2 時間後	2 時間後	6 時間後	24 時間後	直後	2 時間後	4 時間後	6 時間後	24 時間後
cc		%	%	%	%	%	%	%	%	%	%
0.1	6.4	100	25	—	—	—	74	—	—	—	—
0.5	5.4	100	47	21	—	—	75	—	—	—	—
1.0	3.8	100	75	71	65	21	96	57	43	20	—
2.0	2.4	100	96	94	86	32	100	93	86	79	28
3.0	2.2	100	100	96	90	45	100	100	96	90	42
4.0	1.8	100	100	100	94	48	100	100	96	90	48
※ 4.9	1.4	100	100	100	96	50	100	100	96	90	48

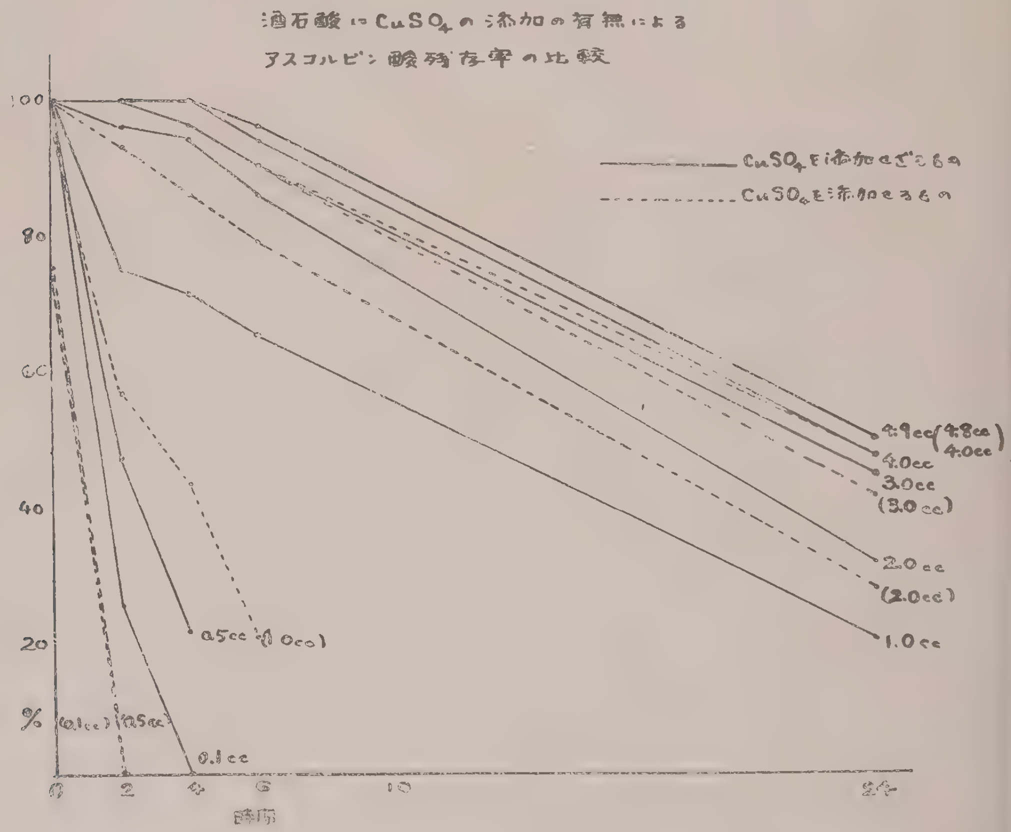
※ $CuSO_4$ を加えたるものは 4.8 cc

第 21 表

pH 2.4 に於けるアスコルビン酸残存率の比較

溶液 pH＝2.0	CuSO$_4$を加えざるもの					CuSO$_4$を加えたるもの				
	直後	2時間後	4時間後	6時間後	２４時間後	直後	2時間後	4時間後	6時間後	２４時間後
	%	%	%	%	%	%	%	%	%	%
枸櫞酸	100	97	94	90	56	96	90	88	88	41
酒石酸	100	96	94	86	32	100	93	86	79	28

第 131 図


酒石酸にCuSO$_4$の添加の有無による

アスコルビン酸残存率の比較

要　　旨

1. 酒石酸はアスコルビン酸の自働酸化に対して有効である。

2. 酒石酸は銅の接触的酸化に対しても相当の抑止作用を有しておる。

3. 枸櫞酸と同一 pH に於て比較して見ると酒石酸より枸櫞酸の方がアスコルビン酸の安定性に対して持続性を有しておる。

第 10 章

ビタミン C の安定性に対する酒石酸加里曹達の効果

酒石酸の塩類として酒石酸加里曹達を用い前章同様、ビタミン C の安定性に就き実験を試みた。

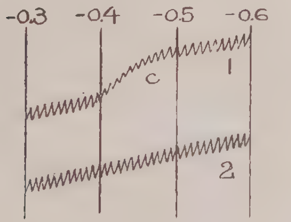
實驗の部

実験に関するすべての條件は前章と同様である。

各々に 0.01 M のアスコルビン酸 0.1 cc を加え之に 0.1 M の酒石酸加里曹達を夫々 0.1、0.5、1.0、2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し酒石酸加里曹達 4.9 cc 添加の場合は燐酸緩衝液は加えなかつた）前章同様時間の経過と共にポーラログラムを撮つた。

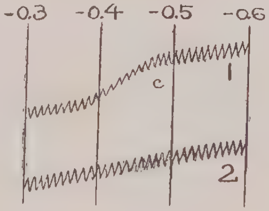
その結果第 22 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を示し、第 132 図にその酸化波の高さの変化を示し、第 133 図〜第 139 図にそのポーラログラムを示した。（図の 1、2、3 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である）

第 133 図



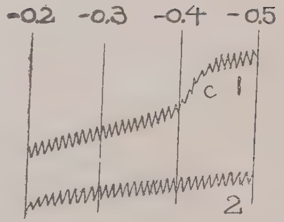
0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸加里曹達 0.1 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.015 volt（1 規定甘汞電極を基準）

第 134 図



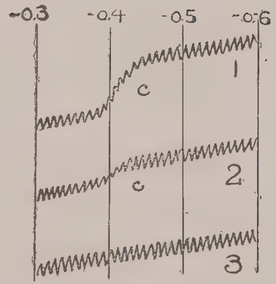
0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸加里曹達 0.5 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.043 volt（1 規定甘汞電極を基準）

第 135 図



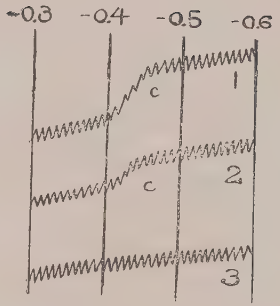
0.01 M アスコルビン酸 0.1 cc に 0.1 M
酒石酸加里曹達 1.0 cc を加え pH 7.0 の
燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.043 volt（1 規定甘汞電
極を基準）

第 136 図



0.01 M アスコルビン酸 0·1 cc に 0.1 M
酒石酸加里曹達 2.0 cc を加え pH 7.0 の
燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.043 volt（1 規定甘汞電
極を基準）
2. −0.043 〃 （ 〃 ）

第 137 図



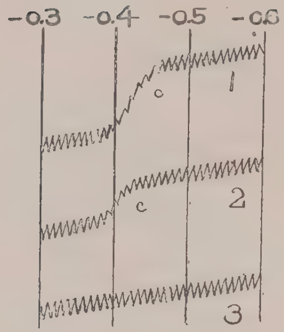
0.01 M アスコルビン酸 0.1 cc に 0.1 M
酒石酸加里曹達 3.0 cc を加え pH 7.0 の
燐酸緩衝液にて 5 ec となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.033 volt（1 規定甘汞電
極を基準）
2 −0.035 〃 （ 〃 ）

第 22 表

酒石酸加里曹達添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

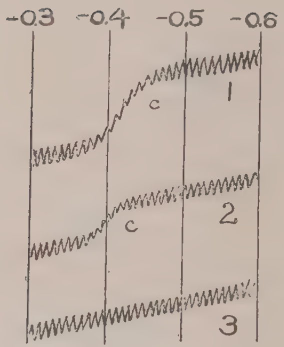
酒石酸加里曹達添加量	pH	直後	2 時間後	4 時間後
酸化波の高さ				
cc		mm	mm	mm
0.1	6.8	5	—	—
0.5	6.6	8	—	—
1.0	6.6	1.0	—	—
2.0	6.6	1.1	2	—
3.0	6.4	1.3	3	—
4.0	6.2	1.5	4	—
4.9	6.0	1.6	5	—
酸化電位 （1 規定甘汞電極を基準）				
cc		volt	volt	volt
0.1	6.8	−0.045	—	—
0.5	6.6	−0.043	—	—
1.0	6.6	−0.043	—	—
2.0	6.6	−0.043	−0.043	—
3.0	6.4	−0.033	−0.035	—
4.0	6.2	−0.028	−0.027	—
4.9	6.0	−0.023	−0.025	—
残存率				
cc		%	%	%
0.1	6.8	100	—	—
0.5	6.6	100	—	—
1.0	6.6	100	—	—
2.0	6.6	100	18	—
3.0	6.4	100	23	—
4.0	6.2	100	27	—
4.9	6.0	100	31	—

第 138 図



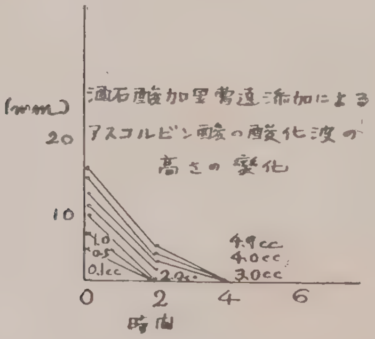
0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸加里曹達 4.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.028 volt（1 規定甘汞電極を基準）
2. −0.027 〃 （〃）

第 139 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M 酒石酸加里曹達 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.023 volt（1 規定甘汞電極を基準）
2. −0.025 〃 （〃）

第 132 図



第 22 表及び第 132 図〜第 139 図に示す如く、此の場合酒石酸加里曹達の添加量を増加してもアスコルビン酸の安定性に対して効果がない。

要　　旨

酒石酸加里曹達はアスコルビン酸の安定性に対しては全然効果でない。

第 11 章

ビタミン C の安定性に対する醋酸の効果

ビタミンの C 安定性に対する醋酸の効果に就いては渡辺氏(85) の研究があり又最近では稲垣氏(86) の報告がある。著者はこれに就いてポーラログラフ的に次の実験を行つた次第である。

實験の部

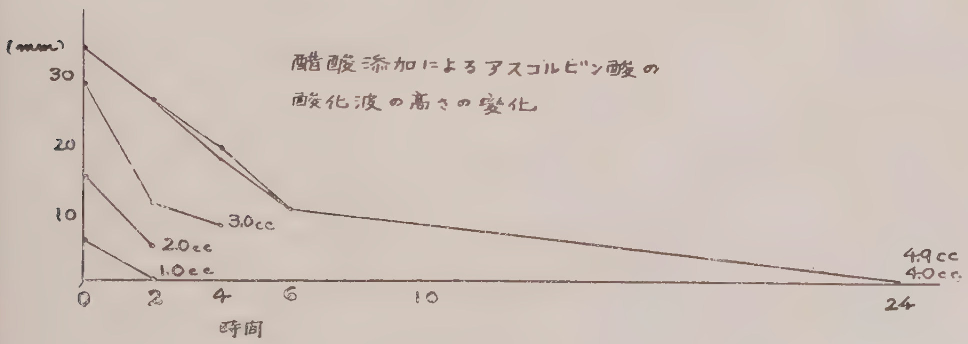
実験に関するすべての條件は前章と同様である。

各々に 0.01 M のアスコルビン酸 0.1 cc を加え之に 0.1 M の醋酸を夫々 0.5、1.0、2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し醋酸 4.9 cc 添加の場合には燐酸緩衝液は加えなかつた）前章同様時間の経過と共にポーラログラムを撮つた。その結果第 23 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 140 図にアスコルビン酸の酸化波の高さの変化を示し、第 141 図～第 146 図にそのポーラログラムを示した。

（図の1、2、3、4、5は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である）

第 23 表、第 140 図～第 146 図に示す如く醋酸の添加量大なる程即ち酸性となる程アスコルビン酸の安定性に対して多少効果はあるが、醋酸の添加量大なるものに於ても 24 時間後には何れもアスコルビン酸を残存していない。又第 4 章以下の場合とその結果を同一 pH に於て比較しても醋酸はアスコルビン酸の安定性に対して劣つている。

第 140 図



第 23 表

醋酸添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

酸化波の高さ

醋酸添加量	pH	直後	2 時間後	4 時間後	6 時間後	24時間後
cc		mm	mm	mm	mm	mm
0.5	6.4	—	—	—	—	—
1.0	5.7	6	—	—	—	—
2.0	4.4	16	5	—	—	—
3.0	3.9	29	11	8	—	—
4.0	3.4	34	26	18	10	—
4.9	2.8	34	26	19	10	—

酸化電位

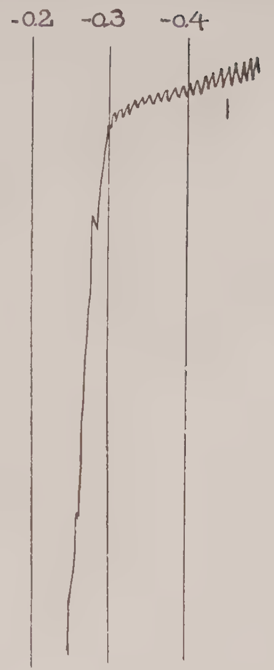
（1 規定甘汞電極を基準）

醋酸添加量	pH	直後	2 時間後	4 時間後	6 時間後	24時間後
cc		volt	volt	volt	volt	volt
0.5	6.4	—	—	—	—	—
1.0	5.7	−0.115	—	—	—	—
2.0	4.4	+0.025	+0.025	—	—	—
3.0	3.9	+0.065	+0.066	+0.066	—	—
4.0	3.4	+0.110	+0.111	+0.106	+0.108	—
4.9	2.8	+0.190	+0.187	+0.191	+0.184	—

残存率

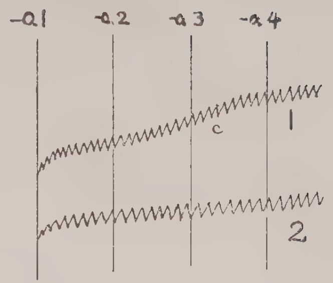
醋酸添加量	pH	直後	2 時間後	4 時間後	6 時間後	24時間後
cc		%	%	%	%	%
0.5	6.4	—	—	—	—	—
1.0	5.7	100	—	—	—	—
2.0	4.4	100	31	—	—	—
3.0	3.9	100	38	28	—	—
4.0	3.4	100	76	53	29	—
4.9	2.8	100	76	56	29	—

第 141 図



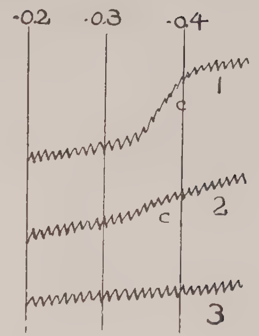
0.01 M アスコルビン酸 0.1 cc に 0.1 M
醋酸 0.5 cc を加え燐酸緩衝液にて 5 cc
となせるもの
即ちアスコルビン酸の濃度は 2.0×10⁻⁴ M

第 142 図



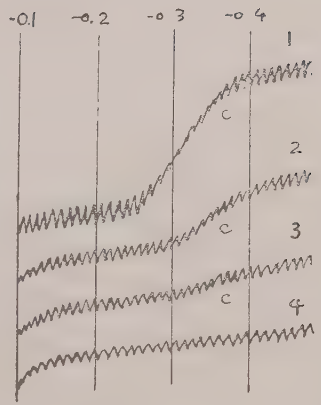
0.01 M アスコルビン酸 0.1 cc に 0.1 M
醋酸 1.0 cc を加え燐酸緩衝液にて 5 cc
となせるもの
即ちアスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.115 volt（1 規定甘汞電極を基準）

第 143 図



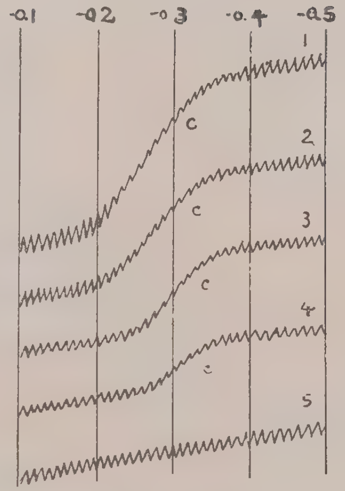
0.01 M アスコルビン酸 0.1 cc に 0.1 M
醋酸 2.0 cc を加え燐酸緩衝液にて 5 cc
となせるもの
即ちアスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.025 volt（1 規定甘汞電極を基準）
2. +0.025 〃 （ 〃 ）

第 144 図



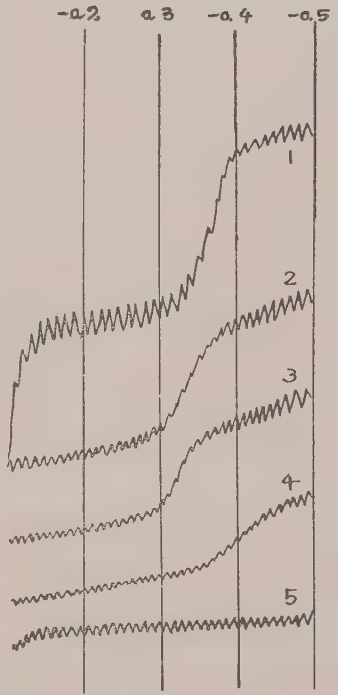
0.01 M アスコルビン酸 0.1 cc に 0.1 M 醋酸 3.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
即ちアスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.065 volt（1 規定甘汞電極を基準）
2. +0.066 〃 （ 〃 ）
3. +0.066 〃 （ 〃 ）

第 145 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M 醋酸 4.0 cc を加え燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.110 volt（1 規定甘汞電極を基準）
2. +0.111 〃 （ 〃 ）
3. +0.106 〃 （ 〃 ）
4. +0.108 〃 （ 〃 ）

第 146 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M 醋酸 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.190 volt（1 規定甘汞電極を基準）
2. +0.187 〃 （ 〃 ）
3. +0.191 〃 （ 〃 ）
4. +0.184 〃 （ 〃 ）

要　　旨

1. 醋酸はアスコルビン酸の自酸化に対し或程度の効果がある。
2. 酒石酸、枸櫞酸に比較してその安定性は劣つている。

第 12 章

ビタミン C の安定性に対する醋酸曹達の効果

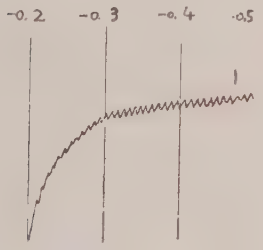
ビタミン C の安定性に対する醋酸曹達の効果を見るため次の実験を試みた次第である。

實驗の部

実驗に関する條件はすべて前章と同様である。

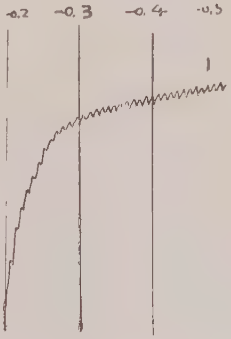
各々に 0.01 M のアスコルビン酸 0.1 cc を加え之に 0.1 M の醋酸曹達を夫々 0.5、1.0、2.0、3.0、4.0、4.9 cc を加え、更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し醋酸曹達 4.9 cc 添加の場合には燐酸緩衝液は加えなかつた）前章同様時間の経過と共にポーラログラムを撮つた。その結果第 24 表に酸化波の高さ及び酸化電位を、第 147 図～第 152 図にそのポーラログラムを示した。（図の 1、2 は夫々アスコルビン酸添加の直後、2 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 147 図



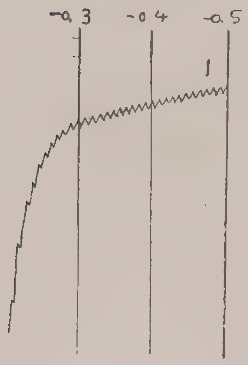
0.01 M アスコルビン酸 0.1 cc に 0.1 M NaAc 0.5 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 148 図



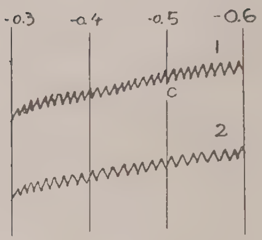
0.01 M アスコルビン酸 0.1 cc に 0.1 M NaAc 1.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 149 図



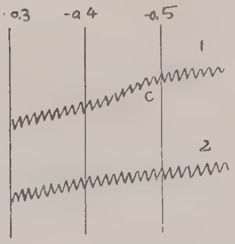
0.01 M アスコルビン酸 0.1 cc に 0.1 M NaAc 2.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 150 図



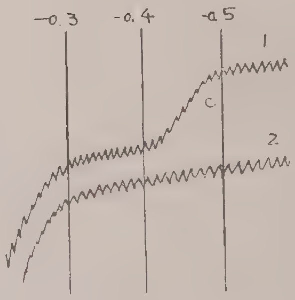
0.01 M アスコルビン酸 0.1 cc に 0.1 M NaAc 3.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 151 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M NaAc 4.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.070 volt（1 規定甘汞電極を基準）

第 152 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M NaAc 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 −0.055 volt（1 規定甘汞電極を基準）

第 24 表

醋酸曹達添加によるアスコルビン酸の酸化波の高さ及び酸化電位

醋酸曹達添加量	pH	直後	2 時間後
酸化波の高さ			
cc		mm	mm
0.5	6.8	—	—
1.0	6.8	—	—
2.0	6.8	—	—
3.0	6.8	2	—
4.0	7.2	5	—
4.9	7.8	16	—
酸化電位 （1 規定甘汞電極を基準）			
cc		volt	volt
0.5	6.8	—	—
1.0	6.8	—	—
2.0	6.8	—	—
3.0	6.8	−0.070	—
4.0	7.2	−0.070	—
4.9	7.8	−0.055	—

第 24 表及び第 147 図～第 152 図に示す如く醋酸曹達の添加 0.5～2.0 cc までは添加直後に於てアスコルビン酸は残存せず、3.0～4.9 cc 添加の場合に於ても 2 時間後に於ては全然アスコルビン酸は残存しない。即ちアスコルビン酸の安定性に対して醋酸曹達は全然効果がない。

要　　旨

1.　アスコルビン酸の安定性に対して醋酸曹達は全然効果がない。

2.　枸櫞酸加里の場合と同一 pH に於て比較しても醋酸曹達はアスコルビン酸の安定性に対して全然効果がない。

第 13 章

ビタミン C の安定性に対する醋酸加里の効果

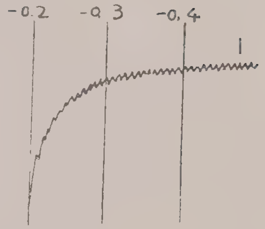
ビタミン C の安定性に対する醋酸加里の効果を見るため次の実験を試みた。

實驗の部

実験に関するすべての條件は前章と同様である。

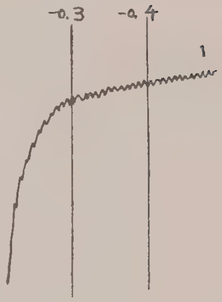
各々に 0.01 M のアスコルビン酸 0.1 cc を加え之に 0.1 M の醋酸加里を夫々 0.5、1.0、2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し醋酸加里 4.9 cc 添加の場合は燐酸緩衝液は加えなかつた（前章同様時間の経過と共にポーラログラムを撮つた。その結果第 25 表にアスコルビン酸の酸化波の高さ及び酸化電位を、第 153 図～第 158 図にそのポーラログラムを示した。（図の 1、2 は夫々アスコルビン酸添加の直後、2 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 153 図



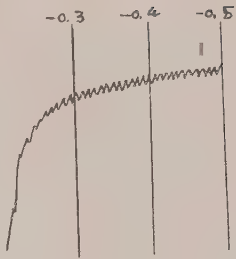
0.01 M アスコルビン酸 0.1 cc に 0.1 M KAc 0.5 cc を加え燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 154 図



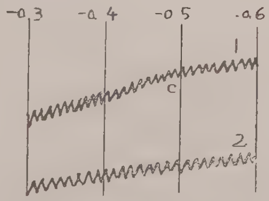
0.01 M アスコルビン酸 0.1 cc に 0.1 M KAc 1.0 cc を加え燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 155 図



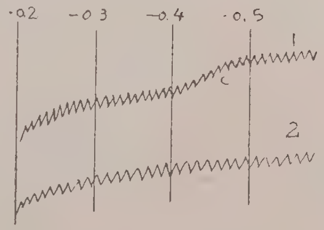
0.01 M アスコルビン酸 0.1 cc に 0.1 M KAc 2.0 cc を加え燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 156 図



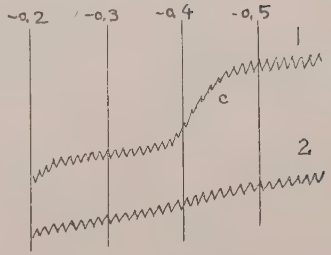
0.01 M アスコルビン酸に 0.1 M KAc 3.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 −0.060 volt（1 規定甘汞電極を基準）

第 157 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M KAc 4.0 cc を加え燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.035 volt（1 規定甘汞電極を基準）

第 158 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M KAc 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.015 volt（1 規定甘汞電極を基準）

第 25 表

醋酸加里添加によるアスコルビン酸の酸化波の高さ及び酸化電位

醋酸加里添加量	pH	直後	2時間後
	酸化波の高さ		
cc		mm	mm
0.5	7.0	—	—
1.0	7.0	—	—
2.0	7.2	—	—
3.0	7.4	4	—
4.0	7.5	7	—
4.9	8.1	17	—
	酸化電位 （1規定甘汞電極を基準）		
cc		volt	volt
0.5	7.0	—	—
1.0	7.0	—	—
2.0	7.2	—	—
3.0	7.4	−0.060	—
4.0	7.5	−0.035	—
4.9	8.1	−0.015	—

第25表及び第153図〜第158図に見る如く醋酸加里の添加0.5〜2.0 ccまでは直後に於てもアスコルビン酸は残存せず。3.0〜4.9 cc添加せる場合に於ても2時間後には全然アスコルビン酸を残存していない。即ち醋酸加里はアスコルビン酸の安定性に対して全然効果がない。

要　　旨

1.　醋酸加里はアスコルビン酸の安定性に対して全然効果がない。

2.　枸櫞酸加里の場合と同一のpHに於て比較しても醋酸加里はアスコルビン酸の安定性に対して全然効果がない。

第 14 章

ビタミンCの安定性に対する蓚酸の効果

ビタミンCの安定性に対する蓚酸の効果に関しては、渡辺氏[87]は蓚酸を以てビタミンCを抽出し、1規定蓚酸溶液の抽出効果は10％メタ燐酸のそれに匹敵すると云い、伊藤氏(88)によれば、メタ燐酸よりも蓚酸は低濃度に於てもその作用で有効であると報告している。この事実は渡辺氏の認めたアルコルビン酸の自酸化に対する場合と同様である。斯る結果より現在アスコルビン酸の抽出定量に使用されているメタ燐酸の代りに蓚酸使用の可能性を渡辺氏の結果と共に推測し得るものであると称している。最近では稲垣氏(89)が蓚酸に関して実験を行つている。著者はポーラログラフ的にビタミンCの安定性に対する蓚酸の効果に関して次の実験を試みた次第である。

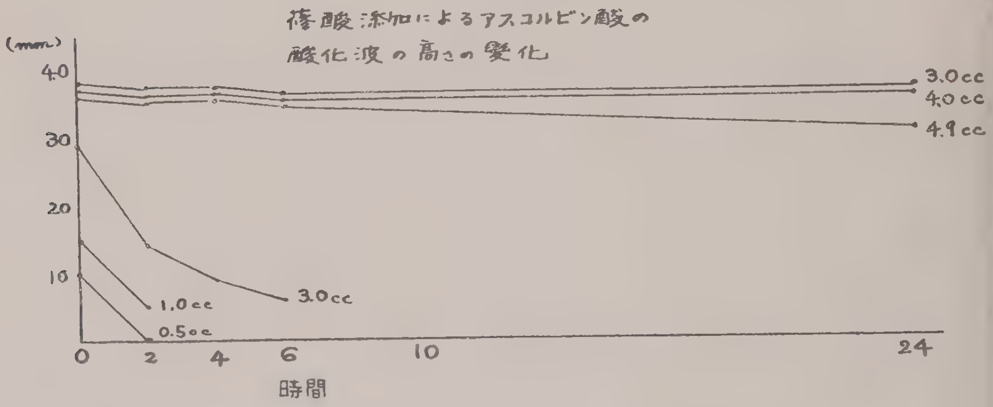
實驗の部

実験に関するすべての條件は前章と同様である。

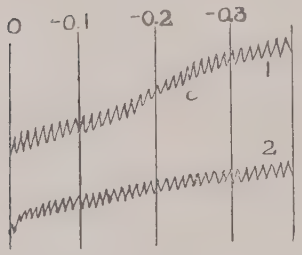
各々に 0.01 M のアスコルビン酸 0.1 cc を加え之に 0.1 M の蓚酸を夫々 0.5、1.0、2.0、3. 4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し蓚酸 4.9 cc 添加 場合は燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つた。そ 結果第 26 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 159 図に酸化波 高さの変化波の高さの変化を示し、第 160 図～第 165 図にそのポーラログラムを示した。

（図の 1、2、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、 24 時間後時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 159 図

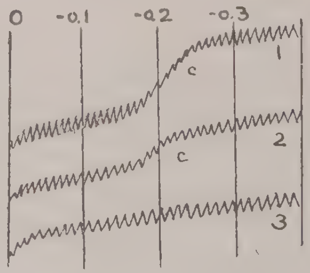


第 160 図



0.01 M アルコルビン酸 0.1 cc に 0.1 M 蓚酸 0.5 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.066 volt（1 規定甘汞電極を基準）

第 161 図



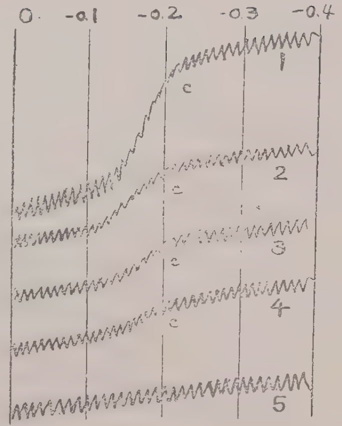
0.01 M アスコルビン酸 0.1 cc に 0.1 M 蓚酸 1.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.061 volt（1 規定甘汞電極を基準）
2. −0.064 〃 （ 〃 ）

第 26 表

蓚酸添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

蓚酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
			酸化波の高さ			
cc		mm	mm	mm	mm	mm
0.5	6.2	10	—	—	—	—
1.0	6.0	15	5	—	—	—
2.0	5.6	29	14	9	6	—
3.0	4.4	38	37	37	36	36
4.0	3.2	37	36	36	35	35
4.9	1.1	36	35	35	34	30
			酸化電位 （1規定甘汞電極を基準）			
cc		volt	volt	volt	volt	volt
0.5	6.2	−0.066	—	—	—	—
1.0	6.0	−0.061	−0.064	—	—	—
2.0	5.6	−0.031	−0.030	−0.030	−0.036	—
3.0	4.4	+0.086	+0.086	+0.089	+0.089	+0.088
4.0	3.2	+0.181	+0.176	+0.179	+0.178	+0.178
4.9	1.1	+0.196	+0.199	+0.198	+0.201	+0.198
			残存率			
cc		%	%	%	%	%
0.5	6.2	100	—	—	—	—
1.0	6.0	100	33	—	—	—
2.0	5.6	100	48	31	21	—
3.0	4.4	100	97	97	95	95
4.0	3.2	100	97	97	95	95
4.9	1.1	100	97	97	95	83

第 162 図

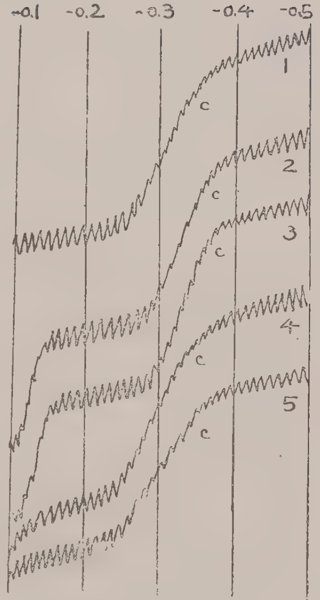


0.01 M アスコルビン酸 0.1 cc に 0.1 M 蓚酸 2.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10⁻⁴ M

酸化電位 1. −0.031 volt（1 規定甘汞電極を基準）
2. −0.030 〃 （ 〃 ）
3. −0.030 〃 （ 〃 ）
4. −0.036 〃 （ 〃 ）

第 163 図

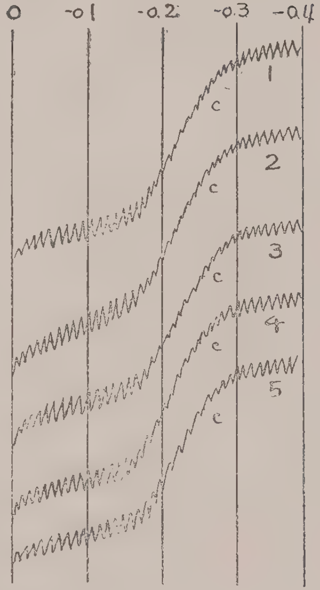


0.01 M アスコルビン酸 0.1 cc に 0.1 M 蓚酸 3.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10⁻⁴ M

酸化電位 1. +0.086 volt（1 規定甘汞電極を基準）
2. +0.086 〃 （ 〃 ）
3. +0.089 〃 （ 〃 ）
4. +0.089 〃 （ 〃 ）
5. +0.088 〃 （ 〃 ）

第 164 図

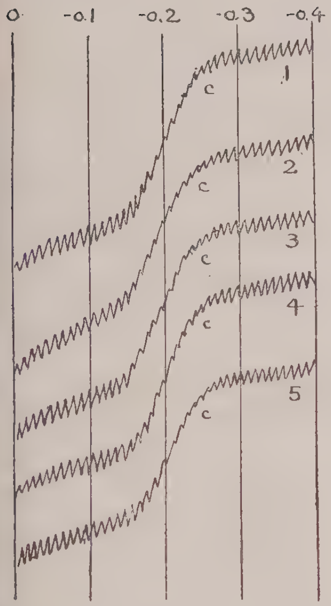


0.01 M アスコルビン酸 0.1 cc に 0.1 M 蓚酸 4.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10⁻⁴ M

酸化電位 1. +0.181 volt（1 規定甘汞電極を基準）
2. +0.176 〃 （ 〃 ）
3. +0.179 〃 （ 〃 ）
4. +0.178 〃 （ 〃 ）
5. +0.178 〃 （ 〃 ）

第 165 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M 蓚酸 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.196 volt（1 規定甘汞電極を基準）
2. +0.199 〃（〃）
3. +0.198 〃（〃）
4. +0.201 〃（〃）
5. +0.198 〃（〃）

第 26 表及び第 159 図〜第 165 図に示す如く蓚酸の添加 0.5〜1.0 cc のものはアスコルビン酸の安定性に対して効果なく、2 cc 加えたるものは多少効果はあるが、3.0、4.0 cc 加えたるものは 24 時間後に於ても 95 % の アスコルビン酸を残存し、4.9 cc 加えたるものに於ては 24 時間後に於て 83 % を残存し、蓚酸の添加量の少ない 3.0 cc 及び 4.0 cc を加えたものよりも多少効果が劣つている。これは 4.9 cc 添加のものは pH が 1.1 にて酸度が高いためか、又は蓚酸 4.9 cc 添加のものは燐酸緩衝液が添加していないためかも知れない。これによつて見ると多少燐酸緩衝液の加えてあるものが効果的であるのかも知れない。兎も角本実験に於ては蓚酸 3.0 cc 及び 4.0 cc 加えたものがアスコルビン酸の安定性に対して最も効果的である。

要旨

1. 蓚酸 3.0 cc 及び 4.0 cc 加えたものは 24 時間後に於ても 95 % のアスコルビン酸を残存し、蓚酸 4.9 cc 加えたるものよりもより効果的でアスコルビン酸の安定性に対して最も効果的である。

2. 第 4 章以下の結果と同一の pH に於て比較して見るに蓚酸添加の場合はその効果は最も優秀なものである。

第 15 章

ビタミン C の安定性に対する蓚酸曹達の効果

ビタミン C の安定性に対する蓚酸曹達の効果を見るためポーラログラフ的に次の実験を試みた。

實験の部

実験に関するすべての條件は前章と同様である。

各々に 0.01 M のアスコルビン酸溶液 0.1 cc を加え之に 0.1 M の蓚酸曹達を夫々 0.5、1.0、

2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し蓚酸曹 4.9 cc 添加の場合には燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つた。

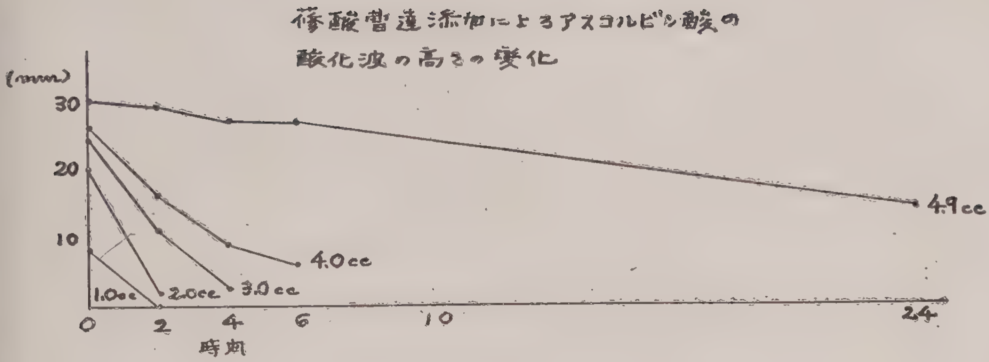
その結果第 27 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を第 166 図に酸化波の高さの変化を示し、第 167 図～第 172 図にそのポーラログラムを示した。（図の 1、2、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 27 表

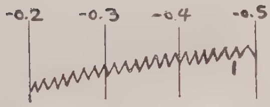
蓚酸曹達添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

蓚酸曹達添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
			酸化波の高さ			
cc		mm	mm	mm	mm	mm
0.5	7.1	—	—	—	—	—
1.0	7.1	8	—	—	—	—
2.0	7.2	15	2	—	—	—
3.0	7.3	25	11	3	—	—
4.0	7.3	26	16	9	6	—
4.9	7.5	30	29	27	27	14
			酸化電位 （1 規定甘汞電極を基準）			
cc		volt	volt	volt	volt	volt
0.5	7.1	—	—	—	—	—
1.0	7.1	−0.064	—	—	—	—
2.0	7.2	−0.054	−0.052	—	—	—
3.0	7.3	−0.056	−0.061	−0.057	—	—
4.0	7.3	−0.044	−0.041	−0.042	−0.046	—
4.9	7.5	−0.006	−0.003	−0.003	−0.004	−0.007
			残存率			
cc		%	%	%	%	%
0.5	7.1	—	—	—	—	—
1.0	7.1	100	—	—	—	—
2.0	7.2	100	13	—	—	—
3.0	7.3	100	44	12	—	—
4.0	7.3	100	61	34	23	—
4.9	7.5	100	97	90	90	47

第 166 図

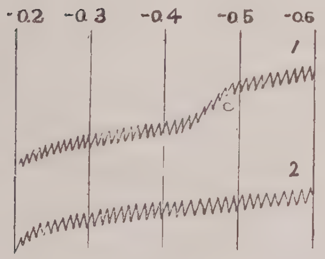


第 167 図



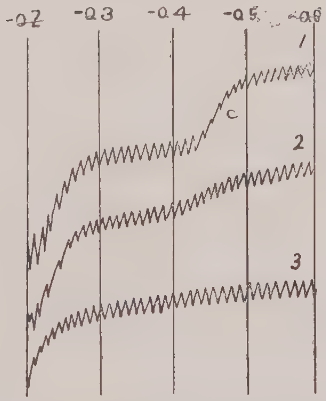
0.01 M アスコルビン酸 0.1 cc に 0.1 M Na-oxalate 0.5 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 168 図



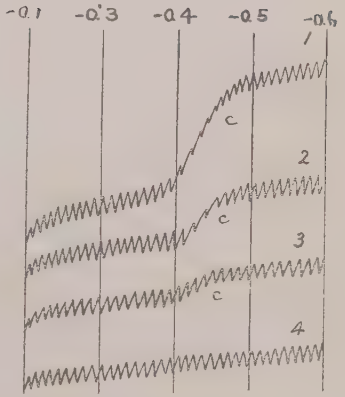
0.01 M アスコルビン酸 0.1 cc に 0.1 M Na-oxalate 1.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.064 volt（1 規定甘汞電極を基準）

第 169 図



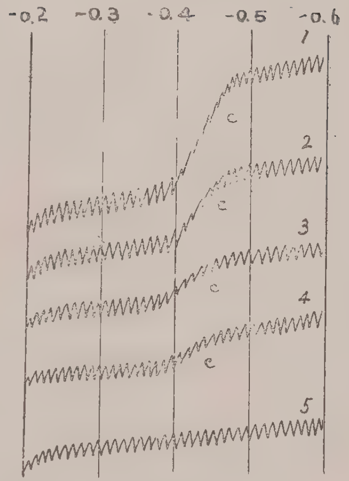
0.01 M アスコルビン酸 0.1 cc に 0.1 M Na-oxalate 2.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.054 volt（1 規定甘汞電極を基準）
2. −0.052 〃 （ 〃 ）

第 170 図



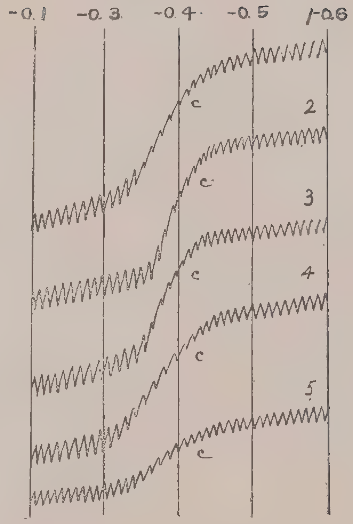
0.01 M アスコルビン酸 0.1 cc に 0.1 M Na-oxalate 3.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0 × 10-4 M
酸化電位 1. −0.056 volt（1 規定甘汞電極を基準）
2. −0.061 〃 （ 〃 ）

第 171 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M Na-oxalate 4.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.041 volt（1 規定甘汞電極を基準）
2. −0.041 〃 （ 〃 ）
3. −0.042 〃 （ 〃 ）
4. −0.046 〃 （ 〃 ）

第 172 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M Na-oxalate 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.006 volt（1 規定甘汞電極を基準）
2. −0.003 〃 （ 〃 ）
3. −0.003 〃 （ 〃 ）
4. −0.004 〃 （ 〃 ）
5. −0.007 〃 （ 〃 ）

第 27 表及び第 166 図〜第 172 図に示す如く蓚酸曹達の添加量大なるものは相当アルコルビン酸の安定性に対して効果があり、蓚酸曹達 4.9 cc 添加せるものは 24 時間後に於ても 47 ％のアスコルビン酸を残存している。醋酸曹達よりも優れている。

要　　旨

1. 蓚酸曹達はアスコルビン酸の自酸化に対して或程度の抑止作用を有す。
2. 醋酸曹達の場合と比較すれば蓚酸曹達は相当の効果を示す。

第 16 章

ビタミン C の安定性に対する蓚酸加里の効果

ビタミン C の安定性に対する蓚酸加里の効果に就いてポーラログラフ的に次の実験を試みた。

實驗の部

実験に関するすべての條件は前章と同様である。

各々に 0.01 M のアスコルビン酸溶液 0.1 cc を加え之に 0.1 M の蓚酸加里を夫々 0.5、1.0、2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し蓚酸加里 4.9 cc 添加の場合には燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つた。

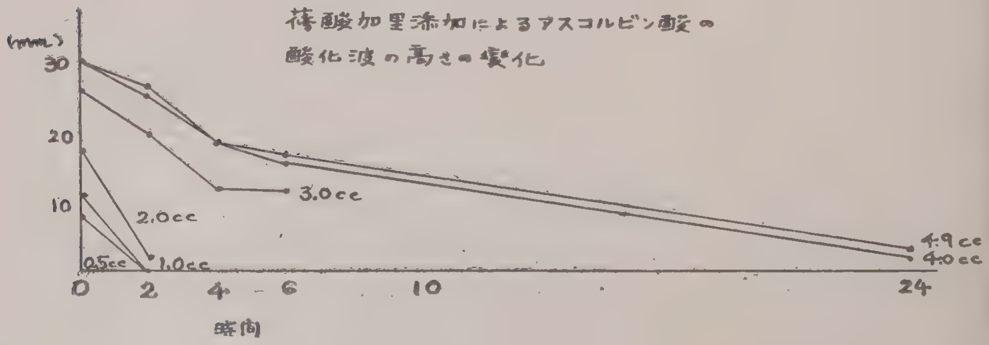
その結果は第 28 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 173 図に酸化波の高さの変化を示し、第 174 図〜第 179 図にそのポーラログラムを示した。（図の 1、2、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後に於ける還元型アスコルビン酸の酸化波の高さを示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 28 表

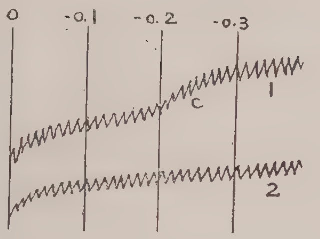
蓚酸加里添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

蓚酸加里添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
		酸化波の高さ				
cc		mm	mm	mm	mm	mm
0.5	7.0	8	—	—	—	—
1.0	7.0	11	—	—	—	—
2.0	7.1	18	2	—	—	—
3.0	7.1	27	20	12	12	—
4.0	7.4	31	26	19	16	2
4.9	7.8	31	27	19	17	3
		酸化電位 (1規定甘汞電極を基準)				
cc		volt	volt	volt	volt	volt
0.5	7.0	−0.087	—	—	—	—
1.0	7.0	−0.082	—	—	—	—
2.0	7.1	−0.072	−0.076	—	—	—
3.0	7.1	−0.035	−0.031	−0.035	−0.036	—
4.0	7.4	−0.015	−0.021	−0.020	−0.019	−0.021
4.9	7.8	−0.010	−0.009	−0 010	−0 011	−0.014
		残存率				
cc		%	%	%	%	%
0.5	7.0	100	—	—	—	—
1.0	7.0	100	—	—	—	—
2.0	7.1	100	11	—	—	—
3.0	7.1	100	74	44	44	—
4.0	7.4	100	84	61	52	6
4.9	7.8	100	87	61	55	10

第 173 図

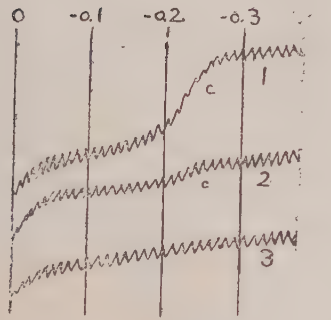


第 174 図



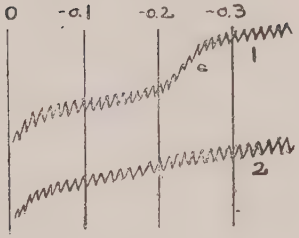
0.01 M アスコルビン酸 0.1 cc に 0.1 M K-oxalate 0.5 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.087 volt（1 規定甘汞電極を基準）

第 176 図



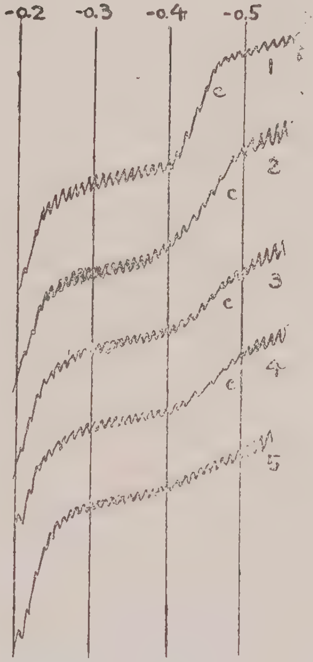
0.01 M アスコルビン酸 0.1 cc に 0.1 M K-oxalate 2.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.072 volt（1 規定甘汞電極を基準）
2. −0.076 〃 （ 〃 ）

第 175 図



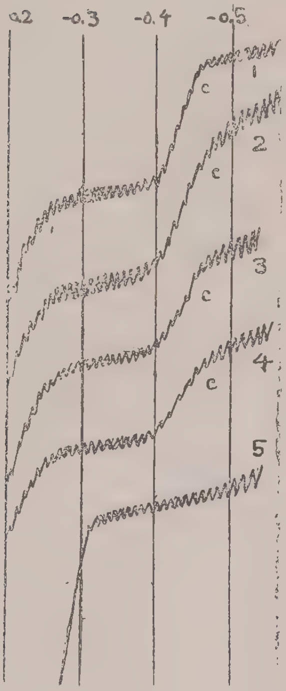
0.01 M アスコルビン酸 0.1 cc に 0.1 M K-oxalate 1.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.082 volt（1 規定甘汞電極を基準）

第 177 図



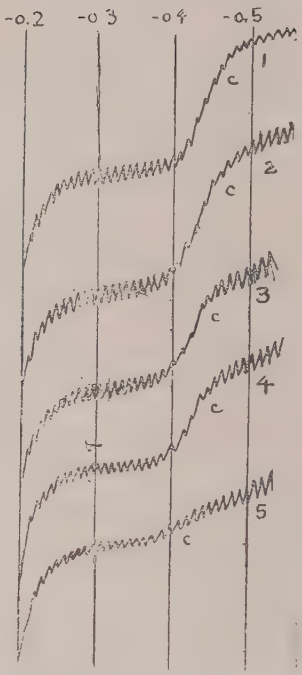
0.01 M アスコルビン酸 0.1 cc に 0.1 M K-oxalate 3.0 cc を加え pH 7.0 の燐酸緩衝液を加 5 cc えとなせるもの
アスコルビン酸の濃度は 2.0×10^{-1} M
酸化電位 1. −0.035 volt（1 規定甘汞電極を基準）
2. −0.031 〃 （ 〃 ）
3. −0.035 〃 （ 〃 ）
4. −0.036 〃 （ 〃 ）

第 178 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M K-oxalate 4.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.015 volt（1 規定甘汞電極を基準）
2. −0.021 〃 （ 〃 ）
3. −0.020 〃 （ 〃 ）
4. −0.019 〃 （ 〃 ）
5. −0.021 〃 （ 〃 ）

第 179 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M K-oxalate 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.010 volt（1 規定甘汞電極を基準）
2. −0.009 〃 （ 〃 ）
3. −0.010 〃 （ 〃 ）
4. −0.011 〃 （ 〃 ）
5. −0.014 〃 （ 〃 ）

第 28 表及び第 173 図～第 179 図に示す如く蓚酸加里の添加量大なるものは或程度アスコルビン酸の安定性に対して効果がある。即ち 24 時間後に於ても蓚酸加里の添加 4.0 cc 以上ののは多少のアスコルビン酸を残存している。蓚酸曹達と比較して 4.9 cc 添加のものは蓚酸加の方が多少劣つている。醋酸の塩類と比較すると蓚酸曹達及び蓚酸加里の方が効果的である。

要　旨

1. 蓚酸加里はアスコルビン酸の安定性に対して或程度の効果がある。
2. 修酸曹達と比較して加里塩よりも曹達塩の方が効果的である。
3. 醋酸の塩類よりも効果的である。

第 17 章

ビタミン C の安定性に対するマレイン酸の効果

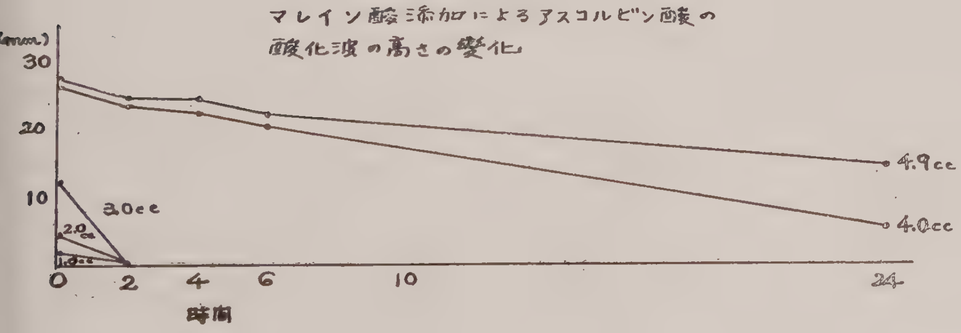
ビタミン C の安定性に対するマレイン酸の効果に関しては稲垣氏(10) の報告があり相当の効を示している。著者はポーラログラフ的に次の実験を試みた。

實驗の部

実験に関するすべての條件は前章と同様である。

各々に 0.01 M のアスコルビン酸溶液 0.1 cc を加え之に 0.1 M のマレイン酸を夫々 0.5、1.0、)、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但しマレイン酸 9 cc 添加の場合は燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムをつた。その結果は第 29 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 180 に酸化波の高さの変化を示し、第 181 図～第 186 図にそのポーラログラムを示した。（図の 2、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 180 図

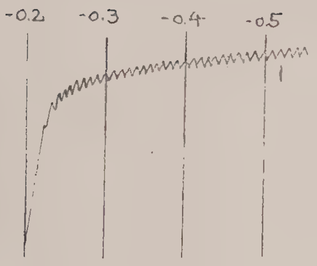


第 29 表

マレイン酸添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

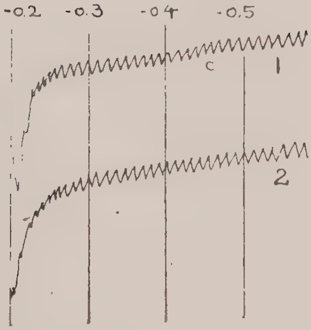
マレイン酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
酸化波の高さ						
cc		mm	mm	mm	mm	mm
0.5	6.6	—	—	—	—	—
1.0	6.4	2	—	—	—	—
2.0	6.0	4	—	—	—	—
3.0	4.8	12	—	—	—	—
4.0	3.2	26	23	22	20	5
4.9	2.2	27	24	24	22	14
酸化電位（1規定甘汞電極を基準）						
cc		volt	volt	volt	volt	volt
0.5	6.6	—	—	—	—	—
1.0	6.4	−0 066	—	—	—	—
2.0	6.0	−0 036	—	—	—	—
3.0	4.8	−0.040	—	—	—	—
4 0	3.2	+0.150	+0.152	+0.151	+0.151	+0.154
4.9	2.2	+0 185	+0.187	+0.186	+0.180	+0.189
残存率						
cc		%	%	%	%	%
0.5	6.6	—	—	—	—	—
1.0	6.4	100	—	—	—	—
2.0	6.0	100	—	—	—	—
3.0	4.8	100	—	—	—	—
4.0	3.4	100	88	84	77	19
4.9	2.2	100	89	89	81	52

第 181 図



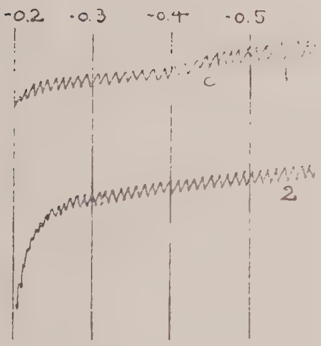
0.01 M アスコルビン酸 0.1 cc に 0.1 M マレイン酸 0.5 を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 182 図



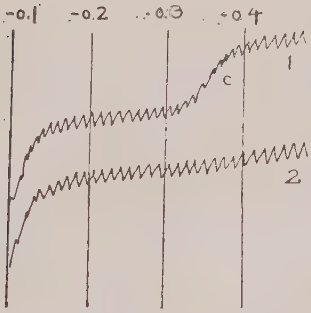
0.01 M アスコルビン酸 0.1 cc に 0.1 M マレイン酸 1.0 cc を加へ pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.066 volt（1 規定甘汞電極を基準）

第 183 図



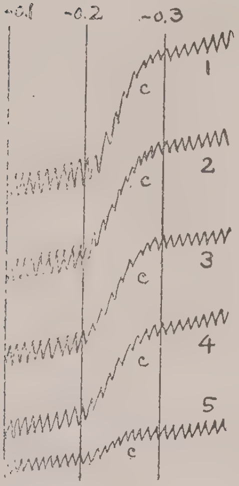
0.01 M アスコルビン酸 0.1 cc に 0.1 M マレイン酸 2.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. −0.036 volt（1 規定甘汞電極を基準）

第 184 図



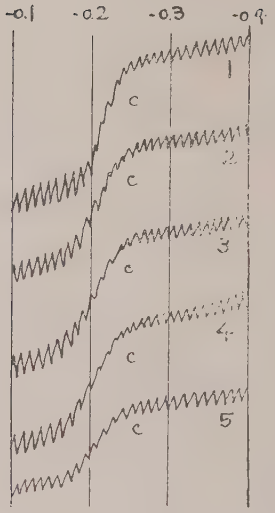
0.01 M アスコルビン酸 0.1 cc に 0.1 M マレイン酸 3.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.040 volt（1 規定甘汞電極を基準）

第 185 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M マレイン酸 4.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10⁻⁴ M
酸化電位 1. +0.150 volt（1 規定甘汞電極を基準）
2. +0.152 〃（〃）
3. +0.151 〃（〃）
4. +0.151 〃（〃）
5. +0.154 〃（〃）

第 186 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M マレイン酸 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10⁻⁴ M
酸化電位 1. +0.185 volt（1 規定甘汞電極を基準）
2. +0.187 〃（〃）
3. +0.186 〃（〃）
4. +0.180 〃（〃）
5. +0.189 〃（〃）

第 29 表及び第 180 図～第 186 図に示す如くマレイン酸の添加 0.5～3.0 cc までは 2 時後に於てアスコルビン酸を残存しないが、4.0 cc 及び 4.9 cc 加えたものは 24 時間後に於てアスコルビン酸を残存し、4.9 cc 加えたものは 50 % を残存している。又第 4 章以下の場同一 pH に於て比較して見ると第 30 表に示す如くマレイン酸を 4.9 cc 加えたものはアスコビン酸の安定性に対して相当の効果を有することを示している。

第 30 表

pH 2.2 に於けるアスコルビン酸の残存率比較

溶液 pH＝2.2	直後	2 時間後	4 時間後	6 時間後	24 時間後
	%	%	%	%	%
枸櫞酸緩衝液	100	97	91	88	60
酒石酸	100	100	96	90	45
マレイン酸	100	89	89	81	52

要　旨

1.　マレイン酸の添加 0.5〜3.0 cc まではアスコルビン酸の安定性に対して全然効果はないが、4 cc 以上添加せるものは 24 時間後に於てもアスコルビン酸を残存し 4.9 cc 添加せるものは約 50 % を残存し相当の効果を示した。

2.　同一の pH のものと比較してマレイン酸はアスコルビン酸の安定性に対して相当の効果を有している。

第 18 章

ビタミン C の安定性に対する乳酸の効果

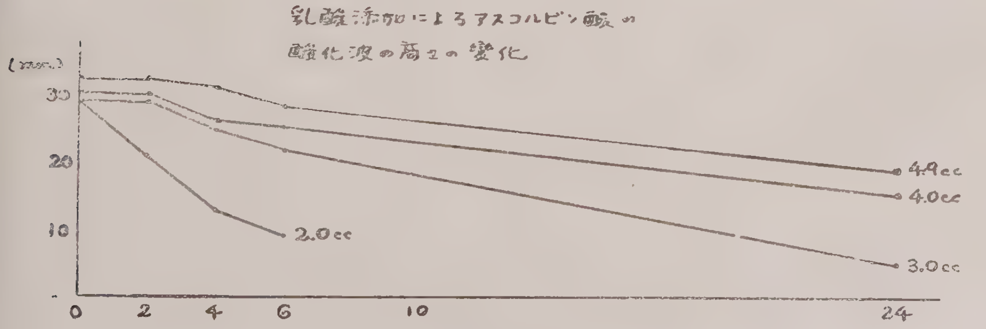
ビタミン C の安定性に対する乳酸の効果に関しては稲垣氏(66) の報告があり相当の安定性を示している。著者はポーラログラフ的にビタミン C の安定性に対する乳酸の効果に関し次の実驗を試みた次第である。

實驗の部

実驗に関するすべての條件は前章と同様である。

各々に 0.01 M のアスコルビン酸溶液 0.1 cc を加え之に 0.1 M の乳酸を夫々 0.5、1.0、2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し乳酸 4.9 cc 添加の場合は燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つた。その結果は第 31 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 187 図に酸化波の高さの変化を示し、第 188 図〜第 193 図にそのポーラログラムを示した。（図の 1、2、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 187 図

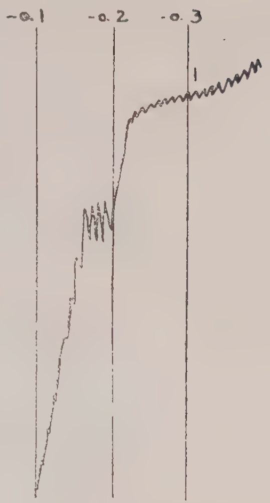


第 31 表

乳酸添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

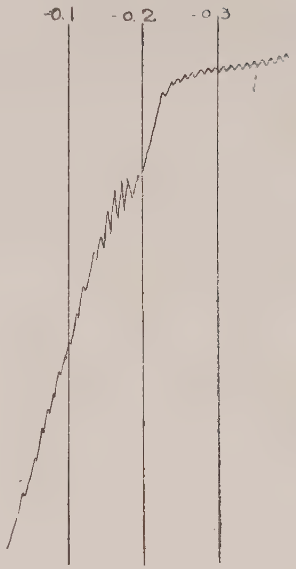
乳酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
酸化波の高さ						
cc		mm	mm	mm	mm	mm
0.5	6.0	—	—	—	—	—
1.0	5.6	—	—	—	—	—
2.0	4.0	29	21	13	9	—
3.0	3.5	29	29	25	22	5
4.0	2.6	30	30	26	25	15
4.9	2.4	32	32	31	28	19
酸化電位 （ 1 規定甘汞電極を基残）						
cc		volt	volt	volt	volt	volt
0.5	6.0	—	—	—	—	—
1.0	5.6	—	—	—	—	—
2.0	4.0	+0.137	+0.137	+0.136	+0.133	—
3.0	3.5	+0.180	+0.185	+0.187	+0.180	+0.182
4.0	2.6	+0.230	+0.232	+0.237	+0.235	+0.233
4.9	2 4	+0.250	+0.252	+0.252	+0.255	+0.252
残存率						
cc		%	%	%	%	%
0.5	6.0	—	—	—	—	—
1.0	5.6	—	—	—	—	—
2.0	4.0	100	72	45	31	—
3.0	3.5	100	100	86	76	17
4.0	2.6	100	100	87	83	50
4.9	2.4	100	100	97	88	59

第 188 図



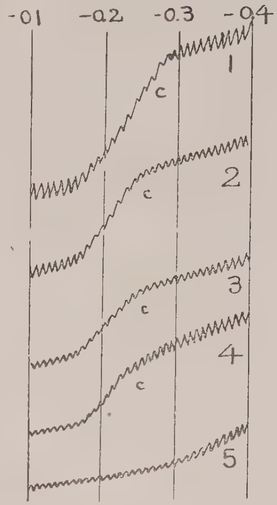
0.01 M アスコルビン酸 0.1 cc に 0.1 M
乳酸 0.5 cc を加え pH 7.0 の燐酸緩衝液
にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10⁻⁴ M

第 189 図



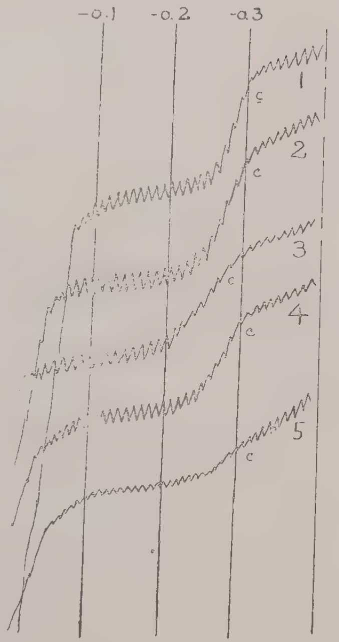
0.01 M アスコルビン酸 0.1 cc に 0.1 M
乳酸 1.0 cc を加え pH 7.0 の燐酸緩衝液
にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10⁻⁴ M

第 190 図



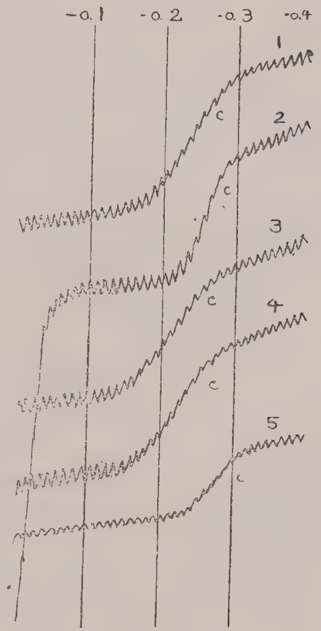
0.01 M アスコルビン酸 0.1 cc に 0.1 M
乳酸 2.0 cc を加え pH 7.0 の燐酸緩衝液
にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10⁻⁴ M
酸化電位 1. +0.137 voit (1 規定甘汞電
極を基準)
2. +0.137 〃 (〃)
3. +0.136 〃 (〃)
4. +0.133 〃 (〃)

第 191 図



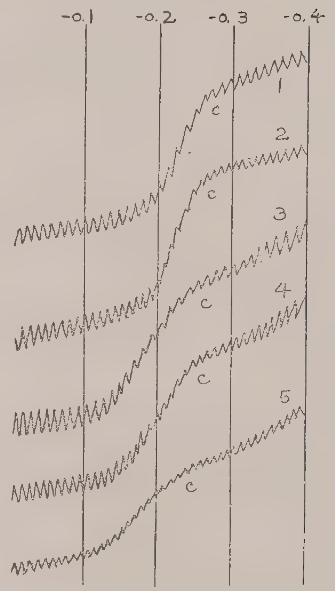
0.01 M アスコルビン酸 0.1 cc に 0.1 M
乳酸 3.0 cc を加え pH 7.0 の燐酸緩衝液
にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.180 volt (1 規定甘汞電
極を基準)
2. +0.185 〃 (〃)
3. +0.187 〃 (〃)
4. +0.180 〃 (〃)
5. +0.182 〃 (〃)

第 192 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M
乳酸 4.0 cc を加え pH 7.0 の燐酸緩衝液
にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.230 volt (1 規定甘汞電
極を基準)
2. +0.232 〃 (〃)
3. +0.237 〃 (〃)
4. +0.235 〃 (〃)
5. +0.233 〃 (〃)

第 193 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M
乳酸 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.250 volt (1 規定甘汞電
極を基準)
2. +0.252 〃 (〃)
3. +0.252 〃 (〃)
4. +0.255 〃 (〃)
5. +0.252 〃 (〃)

第 31 表及び第 187 図〜第 193 図に示す如く乳酸の添加 0.5〜1.0 cc まではアスコルビン酸の安定性に対して効果はないが、2.0 cc 以上添加せるものは相当の効果があり、4.0 cc 以上添加せるものは 24 時間後に於ても 50 % 以上のアスコルビン酸を残存している。乳酸 4.9 cc 添加せるものを第 4 章以下の場合と同一の pH 2.4 の場合と比較すると第 32 表に示す如く乳酸 4.9 cc 添加の場合は最も効果的である。

第 32 表

pH 2.4 に於けるアスコルビン酸の残存率比較

溶液 pH＝2.4	直後	2 時間後	4 時間後	6 時間後	24 時間後
	%	%	%	%	%
枸櫞酸	100	97	94	90	56
酒石酸	100	96	94	86	32
乳酸	100	100	97	88	59

要旨

1. 乳酸はアスコルビン酸の安定性に対して相当の効果を有し、乳酸の添加 4.0 cc 以上のものは 24 時間後に於ても 50 % 以上のアスコルビン酸を残存している。

2. 乳酸 4.9 cc 添加せるものを同一の pH 2.4 の場合即ち枸櫞酸、酒石酸と比較して見るに乳酸の場合がアスコルビン酸の安定性に対して最も効果的である。

第 19 章

ビタミン C の安定性に対する三塩化醋酸の効果

ビタミン C 定量の場合 Tillmans(92), Harris(93) は三塩化醋酸を除蛋白に用い、Mulsin 及び King(94) はメタ燐酸と三塩化醋酸とを共用せるものがアスコルビン酸の安定性に対して有効であると云つている。渡辺氏(95) も三塩化醋酸に就いて同様の報告を行つている。藤田氏(96) は三塩化醋酸による除蛋白法に於てアスコルビン酸が容易に酸化し標準液として用いる純アスコルビン酸液の含量が一定値を示さず時間と共に減少すると報告している。著者はビタミン C の安定化に対する三塩化醋酸の効果に就いてポーラログラフ的に次の実験を試みた次第である。

實驗の部

実験に関するすべての條件は前章と同様である。

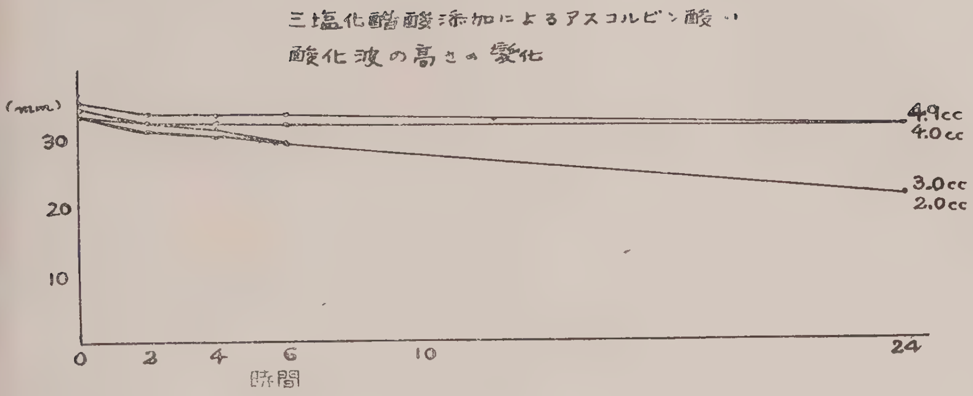
各々に 0.01 M のアスコルビン酸溶液 0.1 cc を加え之に 0.1 M の三塩化醋酸を夫々 0.5、1.0 2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し三塩化醋酸 4.9 cc 添加の場合は燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つた。その結果第 33 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 194 図に酸化波の高さの変化を示し、第 195 図〜第 200 図にそのポーラログラムを示した。（図の 1、2、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 33 表

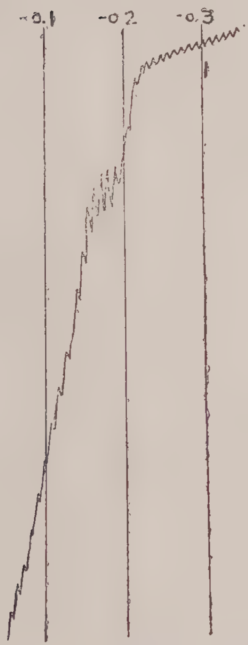
三塩化醋酸添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

三塩化醋酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
		酸化波の高さ				
cc		mm	mm	mm	mm	mm
0.5	6.1	—	—	—	—	—
1.0	5.2	—	—	—	—	—
2.0	1.8	33	31	30	29	21
3.0	1.5	33	32	31	29	21
4.0	1.3	34	32	32	32	31
4.9	1.2	35	33	33	33	31
		酸化電位 （1 規定甘汞電極を基準）				
cc		volt	volt	volt	volt	volt
0.5	6.1	—	—	—	—	—
1.0	5.2	—	—	—	—	—
2.0	1.8	+0.277	+0.276	+0.281	+0.299	+0.280
3.0	1.5	+0.292	+0.293	+0.291	+0.297	+0.291
4.0	1.3	+0.307	+0.308	+0.311	+0.312	+0.311
4.9	1.2	+0.321	+0.318	+0.316	+0.317	+0.316
		残存率				
cc		%	%	%	%	%
0.5	6.1	—	—	—	—	—
1.0	5.2	—	—	—	—	—
2.0	1.8	100	94	91	88	64
3.0	1.5	100	97	94	88	64
4.0	1.3	100	94	94	94	91
4.9	1.2	100	94	91	94	89

第 194 図

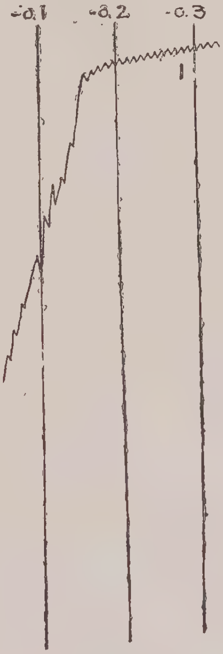


第 195 表



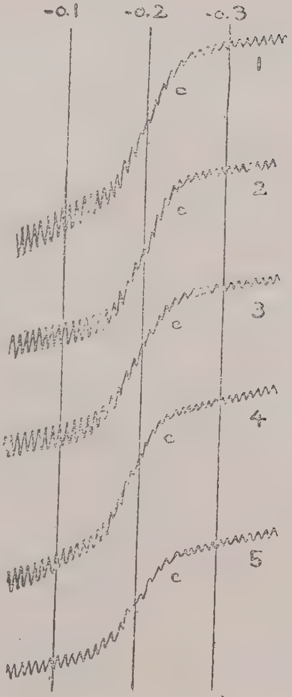
0.01 M アスコルビン酸 0.1 cc に 三塩化醋酸 0.5 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 196 図



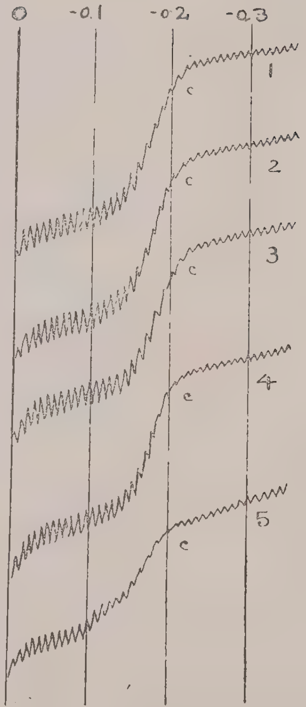
0.01 M アスコルビン酸 0.1 cc に 0.1 M 三塩化醋酸 1.0 cc を加え燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 197 図



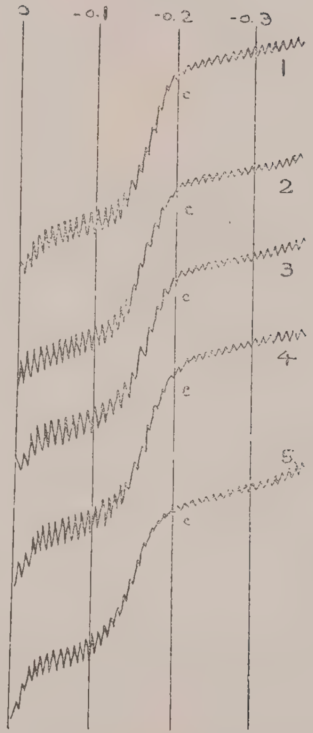
0.01 M アスコルビン酸 0.1 cc に 0.1 M
三塩化醋酸 2.0 cc を加え pH 7.0 の燐酸
緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.277 volt（1 規定甘汞電極を基準）
2. +0.276 〃 （ 〃 ）
3. +0.281 〃 （ 〃 ）
4. +0.279 〃 （ 〃 ）
5. +0.280 〃 （ 〃 ）

第 198 図



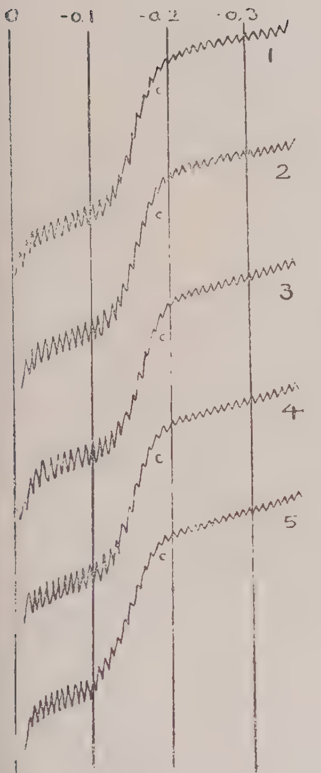
0.01 M アスコルビン酸 0.1 cc に 0.1 M
三塩化醋酸 3.0 cc を加え pH 7.0 の燐酸
緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.292 volt（1 規定甘汞電極を基準）
2. +0.293 〃 （ 〃 ）
3. +0.291 〃 （ 〃 ）
4. +0.297 〃 （ 〃 ）
5. +0.291 〃 （ 〃 ）

第 199 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M
三塩化醋酸 4.0 cc を加え pH 7.0 の燐酸
緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.307 volt（1 規定甘汞電極を基準）
2. +0.308 〃 （ 〃 ）
3. +0.311 〃 （ 〃 ）
4. +0.312 〃 （ 〃 ）
5. +0.311 〃 （ 〃 ）

第 200 図



01 M アスコルビン酸 0.1 cc に 0.1 M
塩化醋酸 4.9 cc を加えたるもの
スコルビン酸の濃度は 2.0×10^{-4} M
化電位 1. +0.321 volt（1 規定甘汞電極を基準）
2. +0.318 〃（〃）
3. +0.316 〃（〃）
4. +0.317 〃（〃）
5. +0.316 〃（〃）

第 33 表及び第 194 図～第 200 図に示す如く三塩化醋酸の添加 1.0 cc 以下は却つて効果はないが 2.0 cc 以上添加せるものは 24 時間後に於ても 60 % 以上のアスコルビン酸を残存し、4.0 cc 以上を添加せるものは 90 % を残存し優秀なる結果を示した。三塩化醋酸 4.9 cc を加えたるもの（pH＝1.2）を、蓚酸 4.9 cc 添加のもの（pH＝1.1）と比較して見ると大体同一の pH であつて 24 時間後に於ける結果を見るに何れもアスコルビン酸の安定性に対して優秀なる効果を有するが三塩化醋酸の方が多少優れている。

要　旨

1. 三塩化醋酸はアスコルビン酸の安定性に対して著しく優秀なる効果を示し、三塩化醋酸 4.0 cc 以上添加せるものは 24 時間後に於ても 90 % のアスコルビン酸を残存している。

2. 大体同一の pH である蓚酸の場合と比較して三塩化醋酸の方が多少効果が優れている。

第 20 章

ビタミン C の安定性に対する琥珀酸の効果

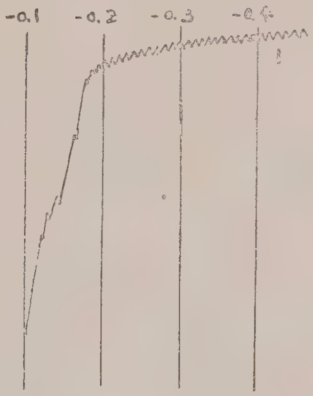
ビタミン C の安定性に対する琥珀酸の効果に関しては稲垣氏(97) の報告がある。著者はポーログラフ的に次の実験を試みた。

實驗の部

実驗に関するすべての條件は前章と同樣である。

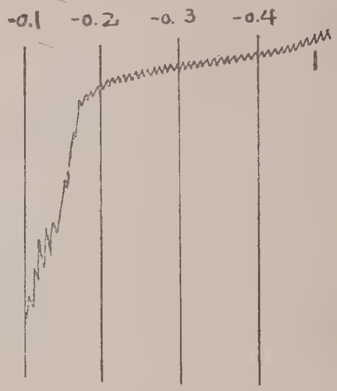
各々に 0.01 M のアスコルビン酸溶液 0.1 cc を加え之に 0.1 M の琥珀酸を夫々 0.5、1.0、2.0、3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但し琥珀酸 4.9 cc 添加の場合には燐酸緩衝液は加えなかつた。）前章同樣時間の經過と共にポーラログラムを撮つた。その結果は第 34 表にアスコルビン酸の酸化波の高さ及び酸化電位を示し、第 201 図〜第 206 図にそのポーラログラムを示した。（図の 1、2、は 夫々アスコルビン酸添加の直後、2 時間後に於ける還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10⁻⁴ M である。）

第 201 図



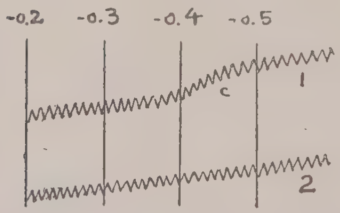
0.01 M アスコルビン酸 0.1 cc に 0.1 M 琥珀酸 1.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 202 図



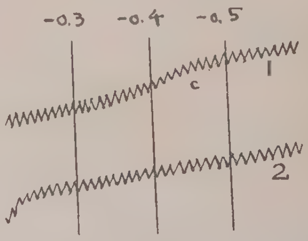
0.01 M アスコルビン酸 0.1 cc に 0.1 M 琥珀酸 1.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M

第 203 図



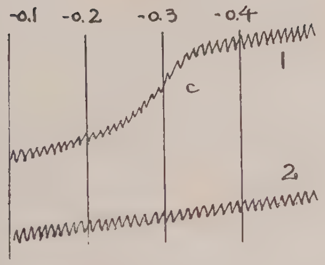
0.01 M アスコルビン酸 0.1 cc に 0.1 M 琥珀酸 2.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.025 volt（1 規定甘汞電極を基準）

第 204 図



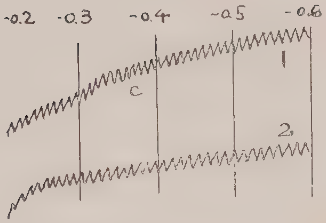
0.01 M アスコルビン酸 0.1 cc に 0.1 M 琥珀酸 3.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.023 volt（1 規定甘汞電極を基準）

第 205 図



0.01 M アスコルビン酸 1.0 cc に 0.1 M 琥珀酸 4.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化需位 1. +0.108 volt（1 規定甘汞電極を基準）

第 206 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M 琥珀酸 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.123 volt（1 規定甘汞電極を基準）

第 34 表

琥珀酸の添加によるアスコルビン酸の酸化波の高さ及び酸化電位

琥珀酸添加量	pH	直後	2 時間後
酸化波の高さ			
cc		mm	mm
0.5	6.6	—	—
1.0	6.4	—	—
2.0	5.6	6	—
3.0	4.6	7	—
4.0	4.0	17	—
4.9	3.6	5	—
酸化電位（1 規定甘汞電極を基準）			
cc		volt	volt
0.5	6.6	—	—
1.0	6.4	—	—
2.0	5.6	+0.025	—
3.0	4.6	+0.023	—
4.0	4.0	+0.108	—
4.9	3.6	+0.123	—

第 34 表及び第 201 図〜第 206 図に示す如く 2 時間後に於て何れもアスコルビン酸を残存せず。琥珀酸の添加量大なるものは相当の酸性を有しているがアスコルビン酸の安定性に対して何等の効果も有していない。

前章迄の結果と比較して見ると琥珀酸の場合は大体同一の pH に於て最悪である。

要　旨

1. アスコルビン酸の安定性に対して琥珀酸は全然効果がない。

2. 第 4 章以下の場合と大体同一の pH に於て比較して琥珀酸の場合はその効果は最悪である。

第 21 章

ビタミン C の安定性に対するメタ燐酸の効果

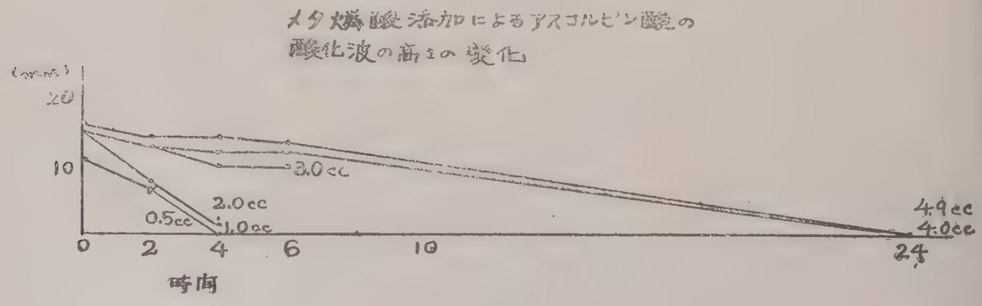
現今メタ燐酸をビタミン C の抽出定量に用いることは常識となつている。藤田氏(98) はメ燐酸を用いるときは極めて安定となりアスコルビン酸の酸化が阻止されることを証明し、又微の銅イオンの存在する場合にメタ燐酸は銅と結合するためにその接触的酸化作用を阻止するもであると報告している。メタ燐酸のビタミン C 定量に於ける優越性については其後 政山(99), Farmer(100), Mulsin(101), Glick(102) Levy(103), Roe(104), Hinsberg(105), Mack(106) 等の追試確を経て廣く應用せらるるに至つた。又メタ燐酸共物でなく Mulsin(107) は 2 % HPO_3+8 % 塩化醋酸を、 Glick(108) は 2 % HPO_3+1N. H_2SO_4 を除蛋白に用いることを提唱している田氏(109) によるとこれ等はメタ燐酸に比して何等優れた点を見出し得ないと称している。
又渡辺氏(101) もメタ燐酸はビタミン C 抽出の安定剤として優秀なる事を報告している。著者ビタミン C の安定性に対するメタ燐酸の効果に就いてポーラログラフ的に次の如き実験を行た次第である。

實驗の部

実験に関するすべての條件は前章と同様である。

各々に 0.01 M のアスコルビン酸 0.1 cc を加え之に 0.1 M のメタ燐酸を夫々 0.5、1.0、2.0 3.0、4.0、4.9 cc を加え更に pH 7.0 の燐酸緩衝液を加えて 5 cc となし（但しメタ燐酸 4.9 c添加のものは燐酸緩衝液は加えなかつた。）前章同様時間の経過と共にポーラログラムを撮つたその結果は第 35 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 207 図に化波の高さの変化を示し、第 208 図～第 213 図にそのポーラログラムを示した。（図の 1、3、4、5 は夫々アスコルビン酸添加の直後、2 時間後、4 時間後、6 時間後、24 時間後に於る還元型アスコルビン酸の酸化波を示す。アスコルビン酸の濃度は 2.0×10^{-4} M である。）

第 207 図

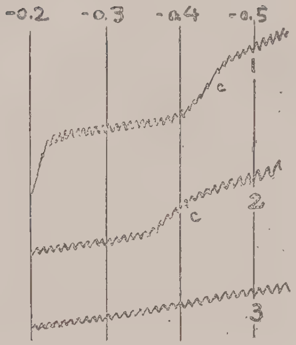


第 35 表

メタ燐酸添加によるアスコルビン酸の酸化波の高さ、酸化電位及び残存率

メタ燐酸添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
酸化波の高さ						
cc		mm	mm	mm	mm	mm
0.5	6.3	11	7	—	—	—
1.0	5.9	11	7	—	—	—
2.0	5.2	15	8	—	—	—
3.0	2.6	15	13	10	10	—
4.0	2.1	15	13	12	12	—
4.9	1.9	16	14	14	13	—
酸化電位（1規定甘汞電極を基準）						
cc		volt	volt	volt	volt	volt
0.5	6.3	−0.021	−0.019	—	—	—
1.0	5.9	−0.036	−0.036	—	—	—
2.0	5.2	−0.049	−0.046	—	—	—
3.0	2.6	+0.163	+0.162	+0.162	+0.160	—
4.0	2.1	+0.178	+0.180	+0.177	+0.173	—
4.9	1.9	+0.208	+0.207	+0.207	+0.203	—
残存率						
cc		%	%	%	%	%
0.5	6.3	100	64	—	—	—
1.0	5.9	100	64	—	—	—
2.0	5.2	100	53	—	—	—
3.0	2.6	100	87	70	70	—
4.0	2.1	100	87	80	80	—
4.9	1.9	100	88	88	81	—

第 208 図

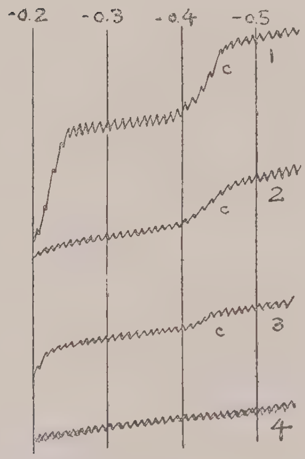


0.01 M アスコルビン酸 0.1 cc に 0.1 M HPO_3 0.5 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. −0.021 volt（1 規定甘汞電極を基準）
2. −0.019 〃 （ 〃 ）

第 210 図

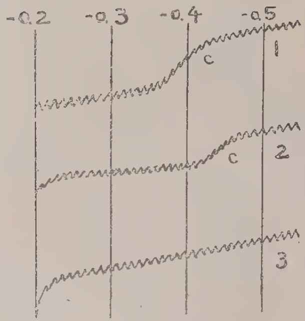


0.01 M アスコルビン酸 0.1 cc に 0.1 M HPO_3 2.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. −0.049 volt（1 規定甘汞電極を基準）
2. −0.046 〃 （ 〃 ）
3. −0.045 〃 （ 〃 ）

第 209 図

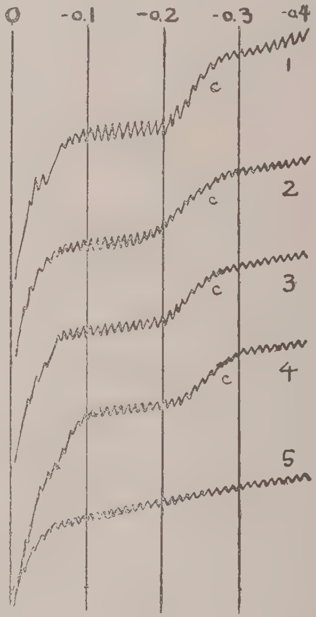


0.01 M アスコルビン酸 0.1 cc に 0.1 M HPO_3 1.0 cc を加え pH 7.0 の燐酸緩衝液を加えて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

酸化電位 1. −0.036 volt（1 規定甘汞電極を基準）
2. −0.036 〃 （ 〃 ）

第 211 図

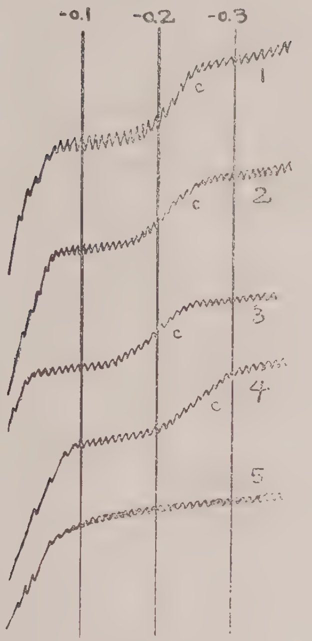


0.01 M アスコルビン酸 0.1 cc に 0.1 M HPO_3 3.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの

アスコルビン酸の濃度は 2.0×10^{-4} M

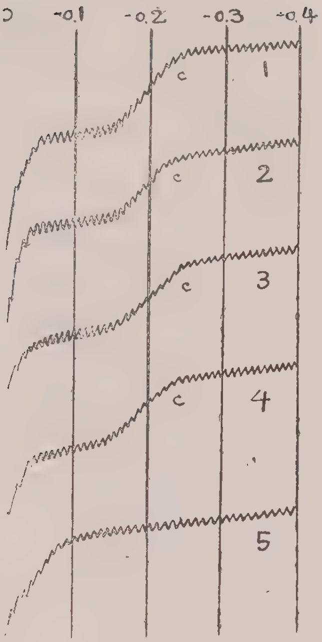
酸化電位 1. +0.163 volt（1 規定甘汞電極を基準）
2. +0.162 〃 （ 〃 ）
3. +0.162 〃 （ 〃 ）
4. +0.160 〃 （ 〃 ）

第 212 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M HPO_3 4.0 cc を加え pH 7.0 の燐酸緩衝液にて 5 cc となせるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.178 volt（1 規定甘汞電極を基準）
2. +0.180 〃（〃）
3. +0.177 〃（〃）
4. +0.173 〃（〃）

第 213 図



0.01 M アスコルビン酸 0.1 cc に 0.1 M HPO_3 4.9 cc を加えたるもの
アスコルビン酸の濃度は 2.0×10^{-4} M
酸化電位 1. +0.208 volt（1 規定甘汞電極を基準）
2. +0.207 〃（〃）
3. +0.207 〃（〃）
4. +0.203 〃（〃）

第 35 表及び第 207 図〜第 213 図に示す如く 0.1 M メタ燐酸の濃度に於てはアスコルビン酸の安定性に対して大した効果はなく 24 時間後に於ては、メタ燐酸 4.9 cc 添加のものにてもアスコルビン酸は全然残存していない。一般にメタ燐酸はビタミン C 抽出には 2 % 即ち約 0.25 M の溶液を用いているが、本実験に於てはすべて 0.1 M の溶液を以てビタミン C 安定性に対する効果に就いて研究を行つているので、此場合も 0.1 M のメタ燐酸溶液にて実験を行つた次第である。0.1 M メタ燐酸を 3.0 cc 以上加えたものは相当の酸度であるが前述の同一の pH に於ける結果と比較してもメタ燐酸は大した効果は示さない。

要　　旨

1. アスコルビン酸の安定性に対してメタ燐酸は 0.1 M 程度の濃度に於ては大した効果は示さない。

2. 第 4 章以下の場合と同一の pH に於ける結果と比較して見るにメタ燐酸は殆んど効果ない。

第 22 章

蜜柑果汁中のビタミン C の安定化に対するメタ燐酸、三塩化醋酸及び乳酸の効果

果汁中のビタミン C 自酸化抑止作用に対しては Zilva(111), Mawson(112), Srinivasan(113), Nair(114), Kertesz(115), Sharp(116), Stieb(117), 奥田(118), 鈴木(119) 及び稲垣氏(120) 等の報告がる。果汁中に含有されるビタミン C は合成 1-アスコルビン酸溶液に比して非常に安定でると云うことは多くの研究者によつて報告されている。 Zilva(121), Mawson(122), はレモン果の抗壊血病効果の安定の原因は pH 2.2 位の高度の酸性なるが故であると述べ、奥田(123), 鈴氏(121) は有機酸イオンの存在によることを指適している。著者は蜜柑果汁に安定剤として三塩醋酸、乳酸、メタ燐酸及び pH 7.0 の燐酸緩衝液を加えた場合の効果を比較するためポーラロラフ的に次の実験を試みた次第である。

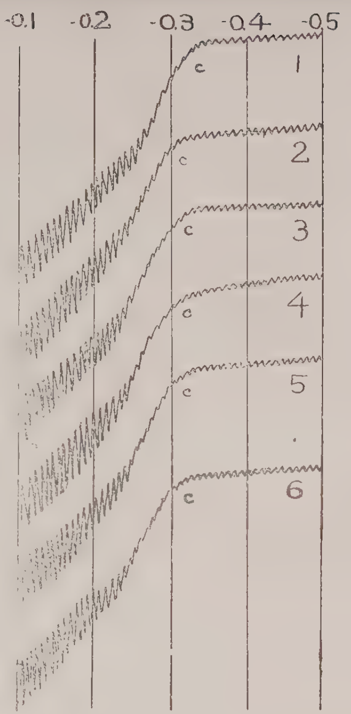
實驗の部

実験に関するすべての條件は前章と同様である。

蜜柑果汁 1.0 cc に 0.1 M の三塩化醋酸 4.0 cc を加えて 5 cc となせるもの、蜜柑果汁 1.0に 0.1 M の乳酸 4.0 cc を加えて 5 cc となせるもの、 蜜柑果汁 1.0 cc に 0.1 M メタ燐4.0 cc を加えて 5 cc となせるもの、蜜柑果汁 1.0 cc に pH 7.0 の燐酸緩衝液 4.0 cc を加て 5 ccとなせるもの。

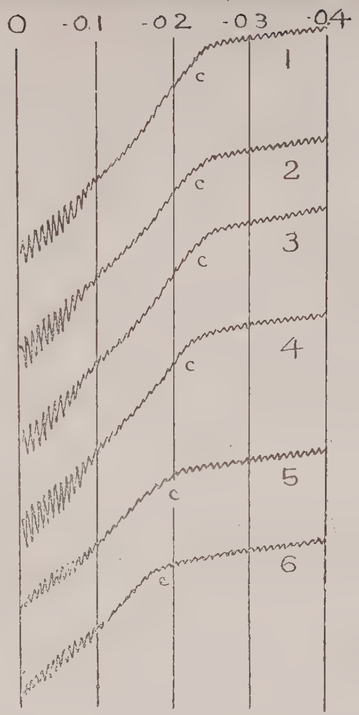
以上 4 箇の試料に対して前章同様時間の経過と共にポーラログラムを撮つた。その結果は36 表にアスコルビン酸の酸化波の高さ、酸化電位及び残存率を、第 214 図～第 217 図にそポーラログラムを示した。(図の 1、2、3、4、5、6 は夫々アスコルビン酸添加の直後、 2 時後、4 時間後、6 時間後、24 時間後、48 時間後に於ける還元型アスコルビン酸の酸化波をす。)

第 214 図



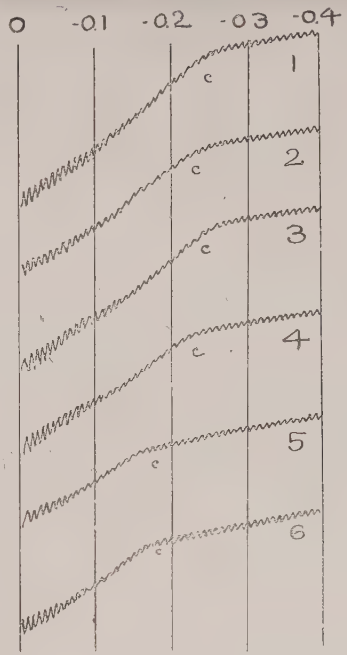
蜜柑果汁 1.0 cc に 0.1 M 三塩化醋酸 4.0 cc を加えたるもの
酸化電位 1. +0.241 volt（1 規定甘汞電極を基準）
2. +0.244 〃 （〃）
3. +0.243 〃 （〃）
4. +0.246 〃 （〃）
5. +0.243 〃 （〃）
6. +0.243 〃 （〃）

第 215 図



蜜柑果汁 1.0 cc に 0.1 M HPO$_3$ 4.0 cc を加えたるもの
酸化電位 1. +0.219 volt（1 規定甘汞電極を基準）
2. +0.216 〃 （〃）
3. +0.215 〃 （〃）
4. +0.213 〃 （〃）
5. +0.220 〃 （〃）
6. +0.218 〃 （〃）

第 216 図



蜜柑果汁 1.0 cc に 0.1 M 乳酸 4.0 cc を加えたるもの
酸化電位 1. +0.214 volt（1 規定甘汞電極を基準）
2. +0.216 〃 （〃）
3. +0.214 〃 （〃）
4. +0.218 〃 （〃）
5. +0.214 〃 （〃）
6. +0.218 〃 （〃）

第 36 表

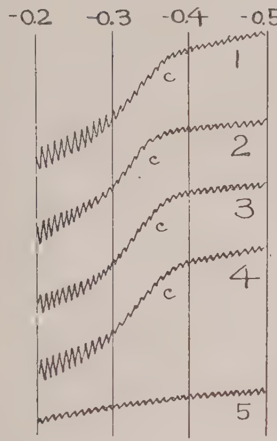
蜜柑果汁に三塩化醋酸、メタ燐酸、乳酸及び pH 7.0 の燐酸緩衝液を加えた時のビタミン C の酸化波の高さ、酸化電位及び残存率

蜜柑果汁 1 cc に加えたる安定剤	pH	直後	2 時間後	4 時間後	6 時間後	24時間後	48時間
酸化波の高さ							
		mm	mm	mm	mm	mm	mm
0.1 M 三塩化醋酸 4.0 cc	1.3	21	21	21	21	21	21
0.1 M メタ燐酸 4.0 cc	2.0	20	20	20	20	20	14
0.1 M 乳酸 4.0 cc	2.5	14	14	14	14	12	10
pH 7.0 の燐酸緩衝液 4.0 cc	5.0	17	17	17	17	—	—
酸化電位 （1 規定甘汞電極を基準）							
		volt	volt	volt	volt	volt	volt
0.1 M 三塩化醋酸 4.0 cc	1.3	+0.241	+0.244	+0.243	+0.246	+0.243	+0.24
0.1 M メタ燐酸 4.0 cc	2.0	+0.219	+0.216	+0.215	+0.213	+0.220	+0.21
0.1 M 乳酸 4.0 cc	2.5	+0.214	+0.216	+0.214	+0.218	+0.214	+0.21
pH 7.0 の燐酸緩衝液 4.0 cc	5.0	+0.076	+0.079	+0.078	+0.076	—	—
残存率							
		%	%	%	%	%	%
0.1 M 三塩化醋酸 4.0 cc	1.3	100	100	100	100	100	100
0.1 M メタ燐酸 4.0 cc	2.0	100	100	100	100	100	70
0.1 M 乳酸 4.0 cc	2.5	100	100	100	100	86	70
pH 7.0 の燐酸緩衝液 4.0 cc	5.0	100	100	100	100	—	—

第 36 表及び第 214 図～第 217 図に示す如く蜜柑果汁に三塩化醋酸 4.0 cc 添加せるもの 48 時間後に於ても 100 % のアスコルビン酸を残存し少しも減少を示していない。0.1 M メタ燐酸を 4.0 cc 添加せるものは 24 時間後迄は 100 % の残存率を示しているが 48 時間後に於ては 70 % に減少している。0.1 M 乳酸 4.0 cc 添加せるものは 24 時間後に於て 86 %、48 時間後に於て 70 % に減少している。之に対し pH 7.0 の燐酸緩衝液を加えたものは 24 時間に於て全然ビタミン C を含有していない。以上の結果より見ると三塩化醋酸で蜜柑果汁のビタミン C の安定剤としては最も効果的であり、メタ燐酸、乳酸も相当の安定性を示している。即ち蜜柑果汁中のビタミン C は添加せる安定剤の水素イオン濃度が相当に低いため 48 時間後に於ても相当の残存率を示している。これを合成アスコルビン酸に前記安定剤を加えたる場合と比較して見るに第 37 表に示す如くである。即ち合成アスコルビン酸に前記安定剤を添加せる場合最も優秀であつた三塩化醋酸の場合は 24 時間後に於てアルコルビン酸は約 90 % に減少しメ

タ燐酸の場合は 24 時間後に於ては全然残存せず、乳酸の場合には約 60 % に減少している。又 pH 7.0 の燐酸緩衝液を加えた場合には直後に於てもアスコルビン酸は全然残存していない。これによつて見ると蜜柑果汁中には既に安定剤となるべき物質の存在することがわかる。

第 217 図



蜜柑果汁 1.0 cc に pH 7.0 の燐酸緩衝液 4.0 cc を加えたるもの

酸化電位 1. +0.076 volt（1 規定甘汞電極を基準）
2. +0.079 〃 （ 〃 ）
3. +0.078 〃 （ 〃 ）
4. +0.076 〃 （ 〃 ）

第 37 表

蜜柑果汁に三塩化醋酸、メタ燐酸、乳酸、燐酸緩衝液を加えた場合と、アスコルビン酸に上記物質を加えた場合との残存率比較

添加せる溶液	pH	直後	2 時間後	4 時間後	6 時間後	24時間後	48時間後
		%	%	%	%	%	%
蜜柑果汁 1 cc+0.1 M 三塩化醋酸 4 cc	1.3	100	100	100	100	100	100
0.01 M アスコルビン酸+0.1 M 三塩化醋酸 4.9 cc	1.2	100	94	94	94	89	—
蜜柑果汁 1 cc+0.1 M メタ燐酸 4 cc	2.0	100	100	100	100	100	70
0.01 M アスコルビン酸+0.1 M メタ燐酸 4.9 cc	1.9	100	88	88	81	—	—
蜜汁果汁 1 cc+0.1 M 乳酸 4 cc	2.5	100	100	100	100	86	70
0.01 M アスコルビン酸+0.1 M 乳酸 4.9 cc	2.4	100	100	97	88	59	—
蜜柑果汁 1 cc+pH 7.0 の燐酸緩衝液 4 cc	5.0	100	100	100	100	-	—
0.01 M アスコルビン酸+pH 7.0の燐酸緩衝液 4.9 cc	7.0	—	—	—	—	—	—

アスコルビン酸の濃度は 2.0×10^{-4} M であつて蜜柑果汁中のビタミン C の濃度と大体一致したものである。

これに就いて稲垣氏(125) は果汁中のビタミン C の安定の原因は其の共存せる酸類のみならず糖類を亦有力なる一因子であり、又酸、糖の共存によりて更に強化せられるものであると報告している通り、蜜柑果汁は此等の物質によつて非常に安定となつているものと思われる。

要旨

1. 蜜柑果汁に安定剤として三塩化醋酸を加えた場合 48 時間後に於ても少しもビタミン C を減少せずに残存しビタミン C の安定性に対して最も効果的である。メタ燐酸、乳酸も 48 時間後に於て 70 % のビタミン C を残存し甚だ効果的である。

2. 蜜柑果汁中のビタミン C は合成アスコルビン酸に比して著しく安定である。これは蜜柑果汁中に既に安定剤となるべき物質即ち酸類、糖類の共存によるものと思われる。

第 23 章

結論

（ビタミン C の安定性に対する効果に就いて）

ビタミン C の安定性に対する効果を研究するため主として有機酸並びにその塩類に就いて第 4 章より前章迄ポーラログラフ的に研究を行つた次第である。その結果を綜合して見るに、

1. ビタミン C の安定性に対する有機酸並びにその塩類の効果順位

第 4 章より前章までに於ける実驗結果を 24 時間後に於てアスコルビン酸を残存せるもののみに就き、24 時間後に於けるアスコルビン酸残存率の大小によりその順位を表示して見ると第 38 表の如くである。即ち蓚酸、三塩化醋酸、乳酸、枸櫞酸、マレイン酸、酒石酸、蓚酸曹達、枸櫞酸加里、枸櫞酸 2 加里、枸櫞酸 1 加里の順にアルコルビン酸の残存率は減少している。これに依つて見ると蓚酸、三塩化醋酸、乳酸、枸櫞酸、マレイン酸、酒石酸は 24 時間後に於て悉く 50 % 以上のアスコルビン酸を残存しアスコルビン酸の安定性に対しその効果著しきものである。

稲垣氏(126) によるとアスコルビン酸の安定性に対する効果はメタ燐酸、マレイン酸、琥珀酸、醋酸、枸櫞酸、三塩化醋酸、乳酸（本研究と同種の酸以外のものは除く）の順にアスコルビン酸の残存率は減少している。本研究に於ては蓚酸の上位にあることは同様であるが、三塩化醋酸、乳酸は上位にあり醋酸は殆んど効果なく、琥珀酸は全然効果なく、又メタ燐酸は 6 時間後迄は相当の残存率を示したが 24 時間後に於ては全然アスコルビン酸を残存していない。此等の点が

多少相違している。勿論此等の相違はアスコルビン酸の濃度、温度、安定剤の濃度、pH 測定時の相違（稲垣氏の場合は 7 時間後、本研究に於ては 24 時間後）等も一部の原因となるかも知れない。

又佐木氏(127) によれば枸橼酸は却つてアスコルビン酸の酸化を促進するもので安定性に対する効果は全然ないと報告しているが、上記稲垣氏の結果及び本研究の結果より推論しても枸橼酸はアスコルビン酸の安定性に対して相当の効果のあることは確実と思われる。

2. ビタミン C の安定性に対する水素イオン濃度の効果

水素イオン濃度とビタミン C 自酸化抑止作用に関しては、第 4 章に述べたる如く多数の人々がその抑止作用が水素イオン濃度によるものであることを証明している。此処に第 4 章より前章迄の結果をその pH により表示し、第 39 表に pH 1.1〜2.0、第 40 表に pH 2.1〜3.0、第 41 表に pH 3.1〜4.0、第 42 表に pH 4.1〜5.0、第 43 表に pH 5.1〜6.0、第 44 表に pH 6.1〜7.0、第 45 表に pH 7.1〜7.8 を示す。

pH 1.1〜3.0 のものは 24 時間後に於て殆んど 50 % 以上のアスコルビン酸を残存している。又第 4 章に於ける pH 7.0〜2.2 の実験結果によれば、pH 2.2 のものが最も効果的であつた。然るに蓚酸の如きは 4.0 cc を添加せるものは pH 3.2 であつて 24 時間後に於て 95 % のアスコルビン酸を残存している。又蓚酸 3.0 cc を添加せるものは pH 4.4 であつて 24 時間後に於て 95 % の残存率を示している。又蓚酸曹達の如きはその 4.9 cc を添加せるものは pH 7.5 であつて 24 時間後に於て 47 % のアスコルビン酸を残存している。又第 39 表〜第 45 表に示す如く同一 pH に於ける場合が沢山あるがその残存率は一定ではない。これによつて見ると必ずしも pH 1.1〜3.0 の如き水素イオン濃度のものがビタミン C の安定性を左右するものではなく稲垣氏(128) も有機酸の構造及び濃度によつて安定性は左右され pH の影響は殆んどないと報告している。

しかし水素イオン濃度がビタミン C の安定性に相当の関係あることは確かと思う。

第 38 表　ビタミン C の安定化に対する効果順位（24 時間後）

順位	アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2 時間後	4 時間後	6 時間後	24時間後
		cc		%	%	%	%	%
1	蓚酸	4.0	3.2	100	97	97	95	95
2	同	3.0	4.4	100	97	97	95	95
3	三塩化醋酸	4.0	1.3	100	94	94	94	91
4	同	4.9	1.2	100	94	94	94	89
5	蓚酸	4.9	1.1	100	97	97	95	83
6	三塩化醋酸	3.0	1.5	100	97	94	88	64
7	同	2.0	1.8	100	94	91	88	64
8	枸櫞酸緩衝液	4.9	2.2	100	97	91	88	60
9	乳酸	4.0	2.4	100	100	97	88	59
10	枸櫞酸	4.9	2.0	100	97	94	94	56
11	同	4.0	2.4	100	97	94	90	56
12	マレイン酸	4.9	2.2	100	89	89	81	52
13	酒石酸	4.0	1.8	100	100	100	96	50
14	乳酸	4.0	2.6	100	100	87	83	50
15	枸櫞酸	3.0	3.0	100	97	94	84	48
16	蓚酸曹達	4.9	7.5	100	97	90	90	47
17	酒石酸	4.0	2.2	100	100	96	90	45
18	枸櫞酸	2.0	5.0	100	97	94	87	42
19	酒石酸	2.0	2.4	100	96	94	86	32
20	枸櫞酸加里	4.9	6.0	100	82	79	74	32
21	同	4.0	6.2	100	82	79	74	28
22	枸櫞酸緩衝液	4.9	4.0	100	84	71	58	26
23	枸櫞酸 2 加里	4.9	5.2	100	89	86	76	25
24	同	4.0	5.7	100	86	83	77	23
25	枸櫞酸加里	3.0	6.2	100	79	77	66	23
26	酒石酸	1.0	3.8	100	75	71	65	21
27	枸櫞酸 2 加里	3.0	5.8	100	86	80	74	20
28	マレイン酸	4.0	3.4	100	88	84	77	19
29	乳酸	3.0	3.5	100	100	86	76	17
30	枸櫞酸 2 加里	2.0	6.3	100	83	74	71	17
31	枸櫞酸緩衝液	4.9	5.0	100	80	68	52	16
32	枸櫞酸 1 加里	4.9	4.2	100	92	78	70	14
33	枸櫞酸緩衝液	4.9	6.0	100	72	55	38	10
34	蓚酸加里	4.9	7.8	100	87	61	55	10
35	枸櫞酸 1 加里	2.0	4.7	100	88	64	58	9
36	枸櫞酸加里	2.0	6.4	100	78	67	65	9
37	枸櫞酸 1 加里	4.0	4.4	100	92	76	65	8
38	同	3.0	4.5	100	94	75	61	8
39	同	1.0	5.0	100	90	61	55	6
40	蓚酸加里	4.0	7.4	100	84	61	52	6

順位は 24 時間後に於けるアスコルビン酸残存率による

第 39 表

pH 1.1～2.0 に於けるアスコルビン酸残存率

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
	cc		%	%	%	%	%
蓚酸	4.9	1.1	100	97	97	95	83
三塩化醋酸	4.9	1.2	100	94	94	94	89
同	4.0	1.3	100	94	94	94	91
酒石酸	4.9	1.4	100	100	100	96	50
三塩化醋酸	3.0	1.5	100	97	94	88	64
同	2.0	1.8	100	94	91	88	64
酒石酸	4.0	1.8	100	100	100	96	50
メタ燐酸	4.9	1.9	100	88	88	81	—
枸櫞酸	4.9	2.0	100	97	94	94	56

第 40 表

pH 2.1～3.0 に於けるアスコルビン酸残存率

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
	cc		%	%	%	%	%
メタ燐酸	4.0	2.1	100	87	88	80	—
枸櫞酸緩衝液	4.9	2.2	100	97	91	88	60
酒石酸	3.0	2.2	100	100	96	90	45
マレイン酸	4.9	2.2	100	89	89	81	52
枸櫞酸	4.0	2.4	100	97	94	90	56
酒石酸	2.0	2.4	100	96	94	86	32
乳酸	4.9	2.4	100	100	97	88	59
同	4.0	2.6	100	100	87	83	50
メタ燐酸	3.0	2.6	100	87	70	70	—
醋酸	4.9	2.8	100	76	56	29	—
枸櫞酸	3.0	3.0	100	97	94	87	48
枸櫞酸緩衝液	4.9	3.0	100	94	88	81	37

第 41 表

pH 3.1～4.0 に於けるアスコルビン酸残存率

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
	cc		%	%	%	%	%
蓚酸	4.0	3.2	100	97	97	95	95
醋酸	4.0	3.4	100	76	53	29	—
マレイン酸	4.0	3.4	100	88	84	77	19
乳酸	3.0	3.5	100	100	86	76	17
琥珀酸	4.9	3.6	100	—	—	—	—
酒石酸	1.0	3.8	100	75	71	65	21
醋酸	3.0	3.9	100	38	28	—	—
乳酸	2.0	4.0	100	72	45	31	—
琥珀酸	4.0	4.0	100	—	—	—	—
枸櫞酸緩衝液	4.9	4.0	100	84	71	58	26

第 42 表

pH 4.1～5.0 に於けるアスコルビン酸の残存率

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
	cc		%	%	%	%	%
枸櫞酸1加里	4.9	4.2	100	92	78	70	14
蓚酸	3.0	4.4	100	97	97	95	95
枸櫞酸1加里	4.0	4.4	100	92	76	65	8
醋酸	2.0	4.4	100	31	—	—	—
枸櫞酸1加里	3.0	4.5	100	94	75	61	8
琥珀酸	3.0	4.6	100	—	—	—	—
枸櫞酸1加里	2.0	4.7	100	88	64	58	9
マレイン酸	3.0	4.8	100	—	—	—	—
枸櫞酸	2.0	5.0	100	97	94	87	42
枸櫞酸1加里	1.0	5.0	100	90	61	55	6
枸櫞酸緩衝液	4.9	5.0	100	80	68	52	16

第 43 表

pH 5.1～6.0 に於けるアスコルビン酸の残存率

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
	cc		%	%	%	%	%
枸櫞酸2加里	4.9	5.2	100	89	86	76	25
メタ燐酸	2.0	5.2	100	53	7	—	—
三塩化醋酸	1.0	5.2	—	—	—	—	—
酒石酸	0.5	5.4	100	47	21	—	—
乳酸	1.0	5.6	—	—	—	—	—
琥珀酸	2.0	5.6	100	—	—	—	—
蓚酸	2.0	5.6	100	48	31	21	—
枸櫞酸1加里	0.5	5.6	100	84	39	32	—
枸櫞酸2加里	4.0	5.7	100	86	83	77	23
醋酸	1.0	5.7	100	—	—	—	—
枸櫞酸2加里	3.0	5.8	100	86	80	74	20
枸櫞酸	1.0	5.8	100	83	57	50	—
メタ燐酸	1.0	5.9	100	64	—	—	—
枸櫞酸	0.5	6.0	100	80	47	40	—
枸櫞酸加里	4.9	6.0	100	82	79	74	33
酒石酸加里曹達	4.9	6.0	100	31	—	—	—
蓚酸	1.0	6.0	100	33	—	—	—
マレイン酸	2.0	6.0	100	—	—	—	—
乳酸	0.5	6.0	—	—	—	—	—
枸櫞酸緩衝液	4.9	6.0	100	72	55	38	10

第 44 表

pH 6.1〜7.0 に於けるアスコルビン酸残存率

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2時間後	4時間後	6時間後	24時間後
	cc		%	%	%	%	%
三塩化醋酸	0.5	6.1	—	—	—	—	—
蓚酸	0.5	6.2	100	—	—	—	—
枸櫞酸加里	4.0	6.2	100	82	79	74	28
同	3.0	6.2	100	79	77	66	23
酒石酸加里曹達	4.0	6.2	100	18	—	—	—
枸櫞酸2加里	2.0	6.3	100	86	74	71	17
メタ燐酸	0.5	6.3	100	64	—	—	—
醋酸	0.5	6.4	—	—	—	—	—
琥珀酸	1.0	6.4	—	—	—	—	—
枸櫞酸加里	2.0	6.4	100	78	67	65	9
酒石酸加里曹達	3.0	6.4	100	23	—	—	—
枸櫞酸	0.1	6.4	100	54	21	—	—
酒石酸	0.1	6.4	100	25	—	—	—
マレイン酸	1.0	6.4	100	—	—	—	—
同	0.5	6.6	100	—	—	—	—
琥珀酸	0.5	6.6	—	—	—	—	—
枸櫞酸加里	1.0	6.6	100	61	52	48	—
酒石酸加里曹達	2.0	6.6	100	—	—	—	—
同	1.0	6.6	100	—	—	—	—
同	0.5	6.6	100	—	—	—	—
枸櫞酸2加里	0.5	6.8	100	73	30	28	—
枸櫞酸加里	0.5	6.8	100	60	36	11	—
醋酸曹達	0.5	6.8	—	—	—	—	—
酒石酸加里曹達	0.1	6.8	100	—	—	—	—
蓚酸加里	1.0	7.0	100	—	—	—	—
同	0.5	7.0	100	—	—	—	—
醋酸加里	0.5	7.0	—	—	—	—	—
枸櫞酸加里	1.0	7.0	100	50	30	8	—
枸櫞酸緩衝液	4.9	7.0	100	29	25	17	—

第 45 表

pH 7.1～7.8 に於けるアスコルビン酸残存率

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2 時間後	4 時間後	6 時間後	24 時間後
	cc		%	%	%	%	%
蓚酸曹達	0.5	7.1	—	—	—	—	—
同	1.0	7.1	100	—	—	—	—
蓚酸加里	2.0	7.1	100	11	—	—	—
同	3.0	7.1	100	74	44	44	—
蓚酸曹達	2.0	7.2	100	13	—	—	—
同	3.0	7.3	100	44	12	—	—
同	4.0	7.3	100	61	34	23	—
蓚酸加里	4.0	7.4	100	84	61	52	6
蓚酸曹達	4.9	7.5	100	97	90	90	47
蓚酸加里	4.9	7.8	100	87	61	55	10

3. ビタミン C の安定性に対する有機酸塩類の効果

有機酸の塩類としては醋酸曹達、醋酸加里、酒石酸加里曹達、蓚酸曹達、蓚酸加里、枸櫞酸加里、枸櫞酸 1 加里、枸櫞酸 2 加里に就いて実験を行つた。

その結果は第 46 表に示す如くである。即ち酒石酸加里曹達は全然効果なく、又醋酸曹達、醋酸加里も共に効果はない。蓚酸曹達及び蓚酸加里は共に相当の効果を示し何れも 4.9 cc 添加せるものは 24 時間後に於ても アスコルビン酸を残存し、蓚酸曹達は 4.9 cc 添加せるものは pH は 7.5 であつて 24 時間後に於ける残存率は 47 % である。蓚酸加里の 4.9 cc 添加せるものは pH は 7.8 であつて 24 時間後に於て 10 % を残存している。これによつて見ると蓚酸の塩類の場合には曹達塩の方が加里塩よりその効果は優秀である。

第 46 表

各種塩類添加によるアスコルビン酸残存率

アスコルビン酸添加せる溶液	溶液添加量	pH	直後	2 時間後	4 時間後	6 時間後	24 時間後
	cc		%	%	%	%	%
酒石酸加里曹達	4.9	6.0	100	31	—	—	—
醋酸曹達	4.9	7.8	100	—	—	—	—
醋酸加里	4.9	8.1	100	—	—	—	—
蓚酸曹達	4.9	7.5	100	97	90	90	47
蓚酸加里	4.9	7.8	100	87	61	55	10
枸櫞酸加里	4.9	6.0	100	82	79	74	33
枸櫞酸 2 加里	4.9	5.2	100	89	86	76	25
枸櫞酸 1 加里	4.9	4.2	100	92	78	70	14

枸櫞酸加里、枸櫞酸 1 加里及び枸櫞酸 2 加里の場合何れも相當の効果があり、添加量の大なるものは皆 24 時間後迄アスコルビン酸を残存している。即ち各々を 24 時間後（4.9 cc 添加の場合）に於ける残存率を比較して見るに枸櫞酸加里は pH 6.0 であつて 33 % を残存し、枸櫞酸 1 加里は pH 4.2 であつて 14 % を残存し、枸櫞酸 2 加里は pH 5.2 で 25 % を残存している。即ち枸櫞酸の加里塩に於て酸性塩よりも中性塩の方がビタミン C の安定性に対して効果が大である。水素イオン濃度を見ると此の場合は逆に酸性よりも中性に近くなる方が却つて効果的である。

4. ビタミン C の安定性に対する酸の構造に依る効果

酸の構造とビタミン C の安定性に就いては渡辺(49), Strohecker(50), 児玉(51) 及び稲垣氏(3 の報告がある。著者は多くの酸類に就いて実験を行つていないので決定的な結果を述べることは出來ないが実験を行つた範囲内に於て述べると、

(1) 硫酸銅を添加せざる場合

A. 一塩基性飽和脂肪酸

一塩基飽和脂肪酸に就いては僅かに醋酸に就いてのみ実験を行つたものであるが、ビタミン C の安定性に対して或程度の効果はある。醋酸の添加量の大なるものに於ても 24 時間後にはアスコルビン酸を残存していない。しかし食料品を酢漬にするのも或程度ビタミン C を保持し得られるものと考えられる。

B. オキシ酸

オキシ酸としてはオキシ一塩基酸として乳酸、オキシ二塩基酸として酒石酸、オキシ三塩基酸として枸櫞酸に就いて実験を行つた。その結果は第 47 表に示す如く何れも 24 時間後に於て 50～60 % のアスコルビン酸を残存し、ビタミン C の安定性に対する効果は非常に良好なものである。

第 47 表

オキシ酸添加によるアスコルビン酸残存率比較

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2 時間後	4 時間後	6 時間後	24 時間後
	cc		%	%	%	%	%
乳酸	4.9	2.4	100	100	97	88	59
酒石酸	4.9	1.4	100	100	100	96	50
枸櫞酸	4.9	2.0	100	97	94	94	56

C. 二塩基性酸

二塩基性酸としては飽和酸の蓚酸、琥珀酸と不飽和酸のマレイン酸に就いて実験を行つた。その結果第 48 表に示す如く蓚酸最もよく（本表に示せるものは蓚酸 4.9 cc 添加せるもの

24 時間後に於ける残存率は 83 % であるが、蓚酸の添加 3.0 cc 及び 4.0 cc 添加せるものは 95 % のアスコルビン酸を残存している。）二個の COOH が直接連結しているものが最もよく、之に反して二個のメチレン基を挾んで二個の COOH が連結している琥珀酸は全然効果がない。

不飽和二塩基酸のマレイン酸は 24 時間後に於て約 50 % のアスコルビン酸を残存し良好なる効果を示す。

尙ほ解理恒数を比較して見ると次の如くであつて

	D. K. 25°C
蓚酸	$K = 10 \times 10^{-2}$
琥珀酸	$K_A = 6.8 \times 10^{-5}$
マレイン酸	$K = 1.3 \times 10^{-2}$

マレイン酸が最も効果的の如くに思われるが此の場合は蓚酸が最も効果的であつた。

第 48 表

二塩基性酸添加によるアスコルビン酸の残存率

アスコルビン酸に添加せる溶液	溶液添加量	pH	直後	2 時間後	4 時間後	6 時間後	24 時間後
	cc		%	%	%	%	%
蓚酸	4.9	1.1	100	97	97	95	83
琥珀酸	4.9	3.6	100	—	—	—	—
マレイン酸	4.9	2.2	100	89	89	81	52

D. 醋酸の塩素置換体

醋酸の塩素置換体としては一塩化醋酸のみに就いて実験を行つた。その結果は 4.9 cc 添加せるものにて 24 時間後に於ける アスコルビン酸残存率は 91 % であつて ビタミン C の安定性に対する効果は蓚酸に次ぐ優秀性を示した。

E. メタ燐酸

他の酸と比較するため同一濃度（0.1 M）のメタ燐酸に就いて実験を行つたが、0.1 M の濃度ではメタ燐酸はアスコルビン酸の安定性に対して或程度の効果はあるが 24 時間後に於てはアスコルビン酸を残存しない。

(2) 硫酸銅を添加せる場合

銅イオンの接触的酸化抑止作用を見るため一部に硫酸銅を加えて実験を行つたが硫酸銅を加えたものも、加えざるものと同一の傾向を示す。

此の稿を終るに臨み終始御懇篤たる御指導御鞭韃を賜つた京都大学教授農学博士舘先生に深謝し、実験に助力されし小坂部勇氏、根本弘毅氏並びに故小池三郎氏に謝意を表す。

Résumè

The author has studied on the determination of vitamin C, influence of hydrogen ions concentration, and effects of organic acids and their salts on the stability of vitamin C by the polarographic method.

Résumè were as follow.

A.

Determination of vitamin C by polarographic method.

(1) Using the mercury sulphate half-cell as anode, a minute quantity of 1-ascorbi acid dissolved in phosphate buffer (pH=7.0) was electrolysed. The oxidation wav of 1-ascorbic acid which had oxidation potential at -0.078 volt was obtained. (conc. of 1-ascorbic acid was 2.0×10^{-4} M)

(2) The height of oxidation wave of 1-ascorbic acid was not constant when treate in the case of (1), but when a minute quantity of citric acid or potassium citrat was added, or rather citric buffer was used in place of phosphate buffer, the heigh of the oxidation wave of 1 ascorbic acid became constant and proportional to th concentration of 1-ascorbic acid. In this case the citric acid or its salt acted as th stabilizer for vitamin C.

(3) This method was so excellent that once when the standard polarogram of 1-ascorbic acid was obtained, the quantitative determination of vitamin C of othe substances could be easily determined in a short time.

(4) By this method, vitamin C which existed in mandarin orange and Asakusanor was determined and compared with what was determined by the indophenol method The results were almost the same, and would be more effective method, because distinct oxidation wave was obtained with the minute quantity of vitamin C by thi method.

(5) On the determination of vitamin C which existed in mandarin orange an Asakusanori, the oxidation potential were a little different from the oxidation potentia of the standard polarogram of 1-ascorbic acid, but when a minute quantity of 1-ascorbic acid was added to the samples of mandarin orange and Asakusanori, th heights of the oxidation waves were proportional at the same potential to the additional volume of 1-ascorbic acid. Thus, these oxidation waves could be proved that they were those waves of vitamin C.

(6) The polarograms in these experiment indicated the oxidation wave of reduced type of vitamin C.

Therefore, in this experiment only the reduced type of vitamin C was studied.

(7) By this polarographic method, vitamin C of many canned fruits were satisfactorily determined.

B.

Influence of hydrogen ions concentration.

(1) The author has studied on the influence of hydrogen ions concentration at pH 2.2—8.0.

In this case the concentration of 1-ascerbic acid was 2.0×10^{-4} M.

(2) The height of the oxidation wave of 1-ascorbic acid was the greatest at pH 2.2, and were proportionrl inversely to the increase of pH value.

Over pH 7, the height of the oxidation wave was decreased extremely.

(3) The oxidation potentials of 1-ascorbic acid were as follow.

pH 2.2	+ 0.244 volt
pH 3.0	+ 0.122 volt
pH 4.0	+ 0.059 volt
pH 5·0	+ 0.003 volt
pH 6.0	− 0.035 volt
pH 7.0	− 0.055 volt
pH 8.0	− 0.081 volt

C.

Effects of organic acids and their salts on the stability of vitamin C.

(1) The order of effects of organic acids and their salts on the stability of vitamin C.

As stabilizer 0.1 M. organic acids or their salts were added and the concentration of 1–ascorbic acid was kept at 2.0×10^{-4} M:

Then the remained 1-ascorbic acid was determined after 24 hours, and the effect were compared. The results were indicated at the table 38.

(2) Effects of hydrogen ions concentration on the stability of vitamin C.

The results were indicated at the table 39 (pH 1.1–2.0), 40 (pH 2.1–3.0), 41 (pH 3.1–4.0), 42 (pH 4.1-5.0), 43 (pH 5.1-6.0), 44 (pH 6.1-7.0), 45 (pH 7.1-7.8)

Generally the higher hydrogen ions concentration was, the better the stability was but there were some exceptions.

(3) Effects of salts of organic acids on the stability of vitamin C.

As the results are indicated at the table 46, potassium oxalate is the best stabilizer of all organic salts used in this study, and potassium salt was more effective tha sodium salt.

Potassium citrate, mono-potassium citrate and di-potassium citrate were quit effective. Of these three salts the neutral salt (potassium citrate) was the most effective

(4) Effects of the structure of organic acid on the stability of vitamin C.

(a) As the saturated monobasic fatty acid, only acetic acid was studied. Aceti acid was effective to some extent.

(b) As oxy–acid, lactic acid (monobasic acid), tartaric acid (dibasic acid), an citric acid (tribasic acid) were studied.

As the results are indicated at table 47, they were very effective after 24 hours There were remained 50–60 % 1–ascorbic acid.

(c) As dibasic acid, oxalic acid, succinic acid (saturated), and malic acid (unsaturated) were studied.

As the results are indicated on the table 48, oxalic acid was excellent and wa the best of all. In this case, it was most effective when the two carboxyl grou were combined directly.

(d) As chlor substituted compound of acetic acid, trichlor acetic acid was studied and this acid was excellent next to the oxalic acid.

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